NINTH REPORT

OF

THE MICHIGAN ACADEMY OF SCIENCE

CONTAINING AN ACCOUNT OF THE ANNUAL MEETING

HELD AT

ANN ARBOR, MARCH 27, 28, 29, 1907.

PREPARED UNDER THE DIRECTION OF THE COUNCIL

BY

E. E. BOGUE

SECRETARY

AND

WALTER G. SACKETT

ASSISTANT SECRETARY

BY AUTHORITY

LETTER OF TRANSMITTAL.

To Hon. Fred M. Warner, *Governor of the State of Michigan:*

Sir—I have the honor to submit herewith the Ninth Annual Report of the Michigan Academy of Science for publication in accordance with Section 14 of Act No. 44 of the Public Acts of the Legislature of 1899.

Respectfully,

Walter G. Sackett,

Assistant Secretary of the Michigan Academy of Science.

Agricultural College, Aug. 31, 1907.

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CONSTITUTION

OF

THE MICHIGAN ACADEMY OF SCIENCE.*

ARTICLE I.

This Society shall be known as "THE MICHIGAN ACADEMY OF SCIENCE."

ARTICLE II: OBJECTS.

The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science.

ARTICLE III: MEMBERSHIP.

The Academy shall be composed of *Resident Members, Corresponding Members, Honorary Members, Patrons* and *Affiliated Societies.*

1. Resident Members shall be persons who are interested in scientific work and resident in the State of Michigan.

2. Corresponding Members shall be persons interested in science, and not resident in the State of Michigan.

3. Honorary Members shall be persons distinguished for their attainments in science, and not resident in the State of Michigan, and shall not exceed twenty-five in number.

4. Patrons shall be persons who have bestowed important favors upon the Academy, as defined in Chapter I, Paragraph 4 of the By-Laws.

5. Resident Members alone shall be entitled to vote and hold office in the Academy.

6. An affiliated society shall be a society accepted by the Council of the Academy, subject to ratification by the Academy at its next regular meeting as having as a principal object the promotion of scientific research in some line or lines, or the diffusion of scientific results in Michigan. Such a society shall qualify as a member exactly as an individual member and shall exercise its rights of membership through a delegate duly certified by the secretary of said society. Said delegate shall have all the rights of any resident member, except that the publications of the Academy shall be sent to the affiliated society as such as long as the dues of said society are paid and the secretary of the Academy not notified of the selection of a successor, and in case such society contains not less than eight resident members of the Academy such delegate shall ex officio be a member of the Council of the Academy, as

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* The history of the Academy will be found in full in the First Annual Report.

hereafter provided. And hereafter in this constitution and by-laws the word "Resident Member" shall be understood to include also said delegates, unless otherwise expressly stated.

ARTICLE IV: Officers.

1. The officers of the Academy shall consist of a President, a Vice President of each Section that may be organized, a Secretary and a Treasurer.

These officers and all past presidents shall constitute an Executive Committee, which shall be called the *Council.*

2. The President shall discharge the usual duties of a presiding officer at all meetings of the Academy, and of the Council. He shall take cognizance of the acts of the Academy and of its officers, delegates of affiliated societies containing a sufficient number of members of the Academy, as provided in Article III, and cause the provisions of the constitution and By-Laws to be faithfully carried into effect. He shall also give an address to the Academy at the closing meeting of the year for which he is elected.

3. The duties of the President in case of his absence or disability shall be assumed by one of the Vice Presidents who shall be designated by the Council.

The Vice Presidents shall be chairmen of their respective sections. They shall encourage and direct research in the special branches of science included within the Sections over which they preside.

4. The Secretary shall keep the records of the proceedings of the Academy and a complete list of the members, with the dates of their election and disconnection with the Academy. He shall also be the Secretary of the Council.

The Secretary shall co-operate with the President in attending to the ordinary affairs of the Society. He shall attend to the preparations, printing and mailing of circulars, blanks and notifications of elections and meetings. He shall superintend other printing ordered by the Academy, or by the President, and shall have charge of its distribution under the direction of the Council.

The Secretary, unless other provision be made, shall also act as *Editor* of the publications of the Academy and as *Librarian* and *Custodian* of property.

5. The Treasurer shall have the custody of all funds of the Academy. He shall keep an account of receipts and disbursements in detail, and this account shall be audited as hereinafter provided.

6. The Academy may elect an *Editor* to supervise all matters connected with the publication of the transactions of the Academy, under the direction of the Council, and to perform the duties of Librarian until such time as the Academy shall make that an independent office.

7. The Council is clothed with executive authority, and with the legislative powers of the Academy in the intervals between the latter's meetings; but no extraordinary act of the Council shall remain in force beyond the next following stated meeting, without ratification by the Academy. The Council shall have control of the publications of the Academy, under the provisions of the By-Laws and of the resolutions from time to time adopted. It shall receive nominations for members, and on approval, shall submit such nominations to the Academy for action. It shall have power to fill vacancies *ad interim*, in any of the offices of the Academy.

8. Terms of Office. The President, Vice Presidents, Secretary, Treasurer and Editor shall be elected annually, and be eligible to re-election without limitation. Delegates shall remain members of the Council as long as qualified, according to Article III.

ARTICLE V: Voting and Elections.

1. *All elections* shall be by ballot. To elect a Resident Member, Corresponding Member, Honorary Member or Patron or impose any special tax shall require the assent of three-fourths of all Resident Members voting.

2. Any member may be expelled by a vote of nine-tenths of all members voting, provided notice that such a movement is contemplated be given at a meeting of the Academy three months previous to such action.

3. Election of Members. Nominations for Resident membership shall be made by two Resident Members, according to a form to be provided by the Council. One of these Resident Members must be personally acquainted with the nominee and his qualifications for membership. The Council shall submit the nominations received by them, if approved, to a vote of the Academy at a regular meeting.

4. Election of Officers. Nominations for office shall be made by the Council as provided in the By-Laws. The nominations shall be submitted to a vote of the Academy at its winter [annual] meeting. The officers thus elected shall enter upon duty at the adjournment of the meeting.

5. At the meeting in which this Constitution is adopted the officers for the ensuing year shall be elected in such manner as the Academy may determine.

ARTICLE VI: Meetings.

1. The Academy shall hold at least two stated meetings a year—a *Summer [or Field] Meeting*, and a *Winter [or Annual] Meeting*. The date and place of each meeting shall be fixed by the Council, and announced by circular at least three months before the meeting. The programme of each meeting shall be determined by the Council, and announced beforehand, in its general features. The details of the daily sessions shall also be arranged by the Council.

2. All members must forward to the Secretary, if possible, before the convening of the Academy, full title of all papers which they propose to present during the meeting, with a statement of the time that each will occupy in delivery and a brief abstract of their contents. From the abstracts thus presented, the Council will determine the fitness of the paper for the programme.

3. This section stricken out April 1, 1898.

4. Special Meeting of the Academy may be called by the Council, and must be called upon the written request of twenty Resident Members.

5. Stated Meetings of the Council shall be held coincidently with the stated meetings of the Academy. Special meetings of the Council may be called by the President at such times as he may deem necessary.

6. Quorum. At meetings of the Academy a majority of those registered in attendance shall constitute a quorum. Four members shall constitute a quorum of the council.

ARTICLE VII: Publications.

The publications of the Academy shall be under the immediate control of the Council, but the Council shall accord to each author the right, under proper restrictions, to publish through whatever channel he may choose.

ARTICLE VIII: Sections.

Members not less than eight in number may by special permission of the Academy unite to form a Section for the investigation of any branch of science. Each Section shall bear the name of the science which it represents, thus: The Section of (Agriculture) of the Michigan Academy of Science.

2. Each Section is empowered to perfect its own organization as limited by the Constitution and By-Laws of the Academy.

ARTICLE IX: Amendments.

This Constitution may be amended at any Winter [Annual] meeting by a three-fourths vote of all the Resident Members present.

BY-LAWS.

CHAPTER I: Membership.

1. No person shall be accepted as a Resident Member unless he pay the dues for the year within three months after notification of his election. An affiliated society, after the secretary has been notified that it will be accepted as affiliated shall also be expected to pay the annual dues, but a commutation of twenty-five dollars shall be accepted for a permanent membership. The annual dues shall be one (1) dollar, payable on or before the annual meeting in advance; but a single prepayment of twenty-five (25) dollars shall be accepted as commutation for life.

2. The sums paid in commutation of dues shall be invested, and the interest used for the ordinary purposes of the Academy during the payer's life, but after his death the sum shall be covered into the Research Fund.

3. An arrearage in payment of annual dues shall deprive a Resident Member of the privilege of taking part in the management of the Academy and of receiving the publications of the Academy. An arrearage continuing over two (2) years shall be construed as notification of withdrawal.

4. Any person eligible under Article III of the Constitution may be elected Patron upon the payment of one hundred (100) dollars to the Research Fund of the Academy.

CHAPTER II: Officials.

1. The President shall countersign, if he approves, all duly authorized accounts and orders drawn on the Treasurer for the disbursement of money.

2. The Secretary, until otherwise ordered by the Academy, shall perform the duties of Editor, Librarian and Custodian of the property of the Society.

3. The Academy may elect an Assistant Secretary.

4. The Treasurer shall give bonds, with two good sureties approved by the Council, in the sum of five hundred dollars, for the faithful and honest performance of his duties, and the safe-keeping of the funds of the Academy. He may deposit the funds in bank at his discretion, but shall not invest them

without the authority of the Council. His accounts shall be balanced on the first day of the Annual Meeting of each year.

5. The minutes of the proceedings of the Council shall be subject to call by the Academy.

CHAPTER III: Election of Members.

1. Nominations for Resident Membership may be proposed at any time on blanks to be supplied by the Secretary.

2. The *form* for the nomination of Resident Members shall be as follows:

In accordance with his desire, we respectfully nominate for Resident Member of the Michigan Academy of Science.

(Full name)

(Address)

(Occupation)

(Branch of science interested in, work already done, and publications, if any)

(Signed by at least two Resident Members.)

The form when filled is to be transmitted to the Secretary.

3. The Secretary shall bring all nominations before the Council at either the winter [Annual] or summer [Field] meeting of the Academy, and the Council shall signify its approval or disapproval of each. (The Secretary is delegated the power, by general action of the Academy, to accept, subject to the ratification of the Academy at its next meeting, applicants at any time upon the recommendation of two members, as now practiced, and upon the payment of one dollar, which shall cover the annual dues for the year in which it is paid, and that only.)

(Minutes 1907.)

4. At the same or next stated meeting of the Academy, the Secretary shall present the list of candidates to the Academy for election.

5. Corresponding Members, Honorary Members, and Patrons shall be nominated by the Council, and shall be elected in the same manner as Resident Members.

CHAPTER IV: Election of Officers.

Section 1. At the Annual Meeting the election of officers shall take place and the officers elected shall enter on their duties at the end of the meeting.

Section 2. The Council shall nominate a candidate for each office, but each Section may recommend to the Council a candidate for its Vice President. Additional nominations may be made by any member of the Academy. All elections shall be made by ballot.

CHAPTER V: Financial Methods.

1. No pecuniary obligation shall be contracted without express sanction of the Academy or the Council. But it is to be understood that all ordinary incidental and running expenses have the permanent sanction of the Academy, without special action.

2. The creditor of the Academy must present to the Treasurer a fully *itemized* bill, *certified* by the official ordering it, and *approved* by the President. The Treasurer shall then pay the amount out of any funds not otherwise appropriated, and the receipted bill shall be held as his voucher.

3. At each annual meeting the President shall call upon the Academy to

choose two members, not members of the Council, to whom shall be referred the books of the Treasurer, duly posted and balanced to the first day of the Annual Meeting as specified in the By-Laws, Chapter III, Paragraph 4. These AUDITORS shall examine the accounts and vouchers of the Treasurer, and any member or members of the Council may be present during the examination. The report of the Auditors shall be rendered to the Academy before the adjournment of the meeting and the Academy shall take appropriate action.

CHAPTER VI: PUBLICATIONS.

1. The publications are in charge of the Council and under their control, limited only as given by Article VII of the Constitution.

2. One copy of each publication shall be sent to each Resident Member, Corresponding Member, Honorary Member, and Patron, and each author shall receive fifty copies of his memoir. This provision shall not be understood as including publications in journals not controlled by the Academy. [By recent ruling, authors receive no reprints free. If reprints are wanted the Academy will pay two-thirds if the author pays one-third the cost of printing not to exceed fifty copies. The author may have as many more than fifty provided he bears the whole expense of those above fifty.] (Minutes of 1906.)

CHAPTER VII: THE RESEARCH FUND.

1. The Research Fund shall consist of moneys paid by the general public for publications of the Academy, of donations made in aid of research, and of the sums paid in commutation of dues according to the By-Laws, Chapter I, Paragraphs 2 and 4.

2. Donors to this fund not members of the Academy, in the sum of twenty-five dollars, shall be entitled without charge to the publications subsequently appearing.

CHAPTER VIII: ORDER OF BUSINESS.

1. The order of business at the Winter [Annual] Meetings shall be as follows:

(1) Call to order by the Presiding Officer.
(2) Introductory ceremonies.
(3) Statements by the President.
(4) Report by the Council.
(5) Report of the Treasurer, and appointment of the Auditing Committee.
(6) Election of officers of the next ensuing administration.
(7) Election of members.
(8) Announcement of the hour and place for the Address of the retiring President.
(9) Necrological notices.
(10) Miscellaneous announcements.
(11) Business motions and resolutions, and disposal thereof.
(12) Reports of committees and disposal thereof.
(13) Miscellaneous motions and resolutions.
(14) Presentation of memoirs.

2. At an *adjourned session*, the order shall be resumed at the place reached on the previous adjournment, but new announcements, motions and resolu-

tions will be in order before the resumption of the business pending at the adjournment of the last preceding session.

3. At the SUMMER [FIELD] MEETING the items of business under numbers (5), (6), (8), (9), shall be omitted.

4. At any SPECIAL MEETING the Order of Business shall be (1), (2), (3), (7), (10), followed by the special business for which the meeting was called.

CHAPTER IX: AMENDMENTS.

These By-Laws may be amended by a majority vote of the members present at any regular meeting.

OFFICERS 1907–1908.

President, Mark S. W. Jefferson, Ypsilanti.
Secretary–Treasurer, E. E. Bogue, Agricultural College.
Assistant Secretary, Walter G. Sackett, Agricultural College.
Librarian, G. P. Burns, Ann Arbor.
Editor of Bulletin, E. E. Bogue, Agricultural College.

Vice-Presidents.

Agriculture, A. C. Anderson, Agricultural College.
Botany, W. E. Praeger, Kalamazoo.
Geography and Geology, E. H. Kraus, Ann Arbor.
Sanitary Science, J. G. Cumming, Ann Arbor.
Science Teaching, S. D. Magers, Ypsilanti.
Zoology, A. G. Ruthven, Ann Arbor.

Past Presidents.

Prof. W. J. Beal, Agricultural College.
Prof. W. H. Sherzer, Ypsilanti.
Bryant Walker, Esq., Detroit.
Prof. V. M. Spalding, Witch Creek, Cal.
Dr. Henry B. Baker, Holland.
Prof. Jacob E. Reighard, Ann Arbor.
Prof. Charles E. Barr, Albion.
Prof. V. C. Vaughan, Ann Arbor.
*Prof. I. C. Russell, Ann Arbor.
Prof. F. C. Newcombe, Ann Arbor.
Dr. A. C. Lane, State Geologist, Lansing.
Prof. W. B. Barrows, Agricultural College.
Dr. James B. Pollock, Ann Arbor.

Council.

The Council is composed of the above named officers and all Resident Past-Presidents.

* Deceased.

MEMBERSHIP OF THE MICHIGAN ACADEMY OF SCIENCE.

April 1, 1907.

*Charter Member. ‡Corresponding Member.

‡Adams, Charles C., Chicago, Ill., Univ. of Chicago, Dept. Zoology.
Alexander, Samuel, Ann Arbor, Mich., 822 Oakland Ave.
Anderson, A. Crosby, Agricultural College, Michigan.
Babcock, Lucy, Kalamazoo, Mich., 428 Elm St.
Bach, Ellen Botsford, Ann Arbor, Mich., S. Main St.
*Baker, Henry B., Holland, Mich., R. F. D. No. 8.
‡Barlow, Bronson, Guelph, Canada, O. A. C.
Barnes, Charles E., Battle Creek, Mich.
*Barrows, Walter B., Agricultural College, Mich.
*Barr, Charles E., Albion, Mich., 111 Oswego St.
‡Bastin, E. S., Washington, D. C., Geol. Survey.
*Beal, W. J. , Agricultural College, Mich.
‡Bell, Albert T., University Place, Nebraska, Wesleyan Univ.
Bennett, Mary E., Ann Arbor, Mich., 541 Elizabeth St.
Bennett, C. W., Coldwater, Mich.
Berger, Henry W., Ann Arbor, Mich.
Biglow, S. L., Ann Arbor, Mich., 1520 Hill St.
Bissell, John H., Detroit, Mich., Bank Chambers.
Blain, Alexander W., Detroit, Mich., 131 Elmwood Ave.
Bogue, E. E., Agricultural College, Mich.
Bordner, J. L. Ann Arbor, Mich., 620 Monroe St.
*‡Bovie, W. T., Yellow Springs, Ohio.
Brenton, Samuel U. S., Detroit, Mich., 121 Alexandrine Ave.
Bretz, J. H., Flint, Mich.
Bricker, J. I., West Saginaw, Mich.
Brotherton, W. A., Rochester, Mich.
‡Brown, R. A., Boone Grove, Ind.
Brown, C. W., Agricultural College, Mich.
‡Bullock, D. S., Jemuco, Chili, S. Am., 75 Casilla, Mishion, Aurcania.
Burnett, C. T., Ann Arbor, Mich.
Burnham, Ernst, Kalamazoo, Mich.
Burns, G. P., Ann Arbor, Mich., Botanical Laboratory.
Bushnell, L. D., Madison, Wis., Univ. of Wisconsin.
Byers, I. W., Iron River, Mich.
Calkins, R. D., Mt. Pleasant, Mich., Central Normal School.
‡Charlton, Orlando C., Chicago, Ill., 5754 Woodlawn Ave.
Christian, E. A., Pontiac, Mich.
Clark, L. T., Detroit, Mich., Park, Davis & Co.
‡Clawson, A. B., Madison, Wis.
‡Cole, Leon J., Cambridge, Mass., 37 Mellin St.
Collin, H. P., Coldwater, Mich.
*Connor, Leartus, Detroit, Mich., 91 LaFayette Ave.

Cooper, Wm. F., Lansing, Mich., Box 244.
Cooper, Wm., S., Detroit, Mich., 1015 Jefferson Ave.
*Courtis, W. M., Detroit, Mich., 706 Hammond Bldg.
Cumming, Jas. G., Ann Arbor, Mich.
Dachnowski, Alfred, Orchard Lake, Mich.
Dandeno, J. B., Agricultural College, Mich.
Davies, Murig L., Bay City, Mich.
*Davis, Chas. A., Ann Arbor, Mich., 303 S. Division St.
Dawson, Jean, Ann Arbor, Mich., 2093 Ingalls St.
‡Denton, Minna C., Chicago, Ill., Lewis Inst.
‡Dixon, Chas. Y., Amhurstburg, Ontario.
*Dodge, Chas. K., Port Huron, Mich.
Doty, Jessie R., Alma, Mich.
Downing, E. R., Marquette, Mich., Normal School.
‡Duerden, James E., Grahamstown, Cape Colony, S. Africa.
Dumphy, Geo. W., Quincey, Mich.
Dunbar, Frances J., Ann Arbor, Mich., 322 S. Fifth Ave.
‡Edwards, S. F., Guelph, Ontario, Canada.
Farrand, Bell S., Agricultural College, Mich.
*Farwell, O. A., Detroit, Mich., 449 McClellan St.
Fischer, O. E., Detroit, Mich., 507 Field Ave.
Frapwell, A. P., Ann Arbor, Mich.
Gilchrist, Maude, Agricultural College, Mich.
Gillmore, Gertrude A., Detroit, Mich., 27 Charlotte Ave.
Glaser, Otto C., Ann Arbor, Mich.
Goddard, Mary A., Ypsilanti, Mich., 316 Adams St.
Gohn, H. M., St. Johns, Mich.
Gordon, W. C., Houghton, Mich.
Grove, J. M., Hillsdale, Mich.
‡Hall, Aspah, Washington, D. C., Naval Observatory.
‡Hankinson, Thos. L., Charleston, Ill.
Hang, Bernice L., Detroit, Mich., 1130 Third Ave.
Harvey, Nathan A., Ypsilanti, Mich.
Harvey, Caroline, Detroit, Mich., 51 Winder St.
Haynes, Julia A., Kalamazoo, Mich.
Hibbard, R. P., Ann Arbor, Mich.
Hinsdale, W. B., Ann Arbor, Mich.
Hobbs, Wm. H., Ann Arbor, Mich.
‡Holt, W. P., Toledo, Ohio, 1004 Jefferson Ave.
Hoover, J. C., Ann Arbor, Mich., 1340 Volland St.
Hornbeck, H. U., Traverse City, Mich.
Hubbard, Lucius L., Houghton, Mich.
Hunt, W. F., Ann Arbor, Mich.
Jamieson, Clara O., Ann Arbor, Mich.
Jefferson, M. S. W., Ypsilanti, Mich., 14 Normal St.
Jeffery, J. A., Agricultural College, Mich.
‡Johnson, J. A., Morgantown, W. Va.
Jopling, Wm., Owosso, Mich.
Kauffman, C. H., Ann Arbor, Mich.
Kiefer, Guy L., Detroit, Mich.
King, Louisa (Mrs.), Alma, Mich.
King, Francis M., Alma, Mich.
‡Kofoid, Chas. A., Berkeley, Cal., Univ. of California.

Kraus, Edw. H., Ann Arbor, Mich., 548 Thompson St.
‡Landen, Clarence H., Cleveland, Ohio, 89 Arlington St.
*Lane, Alfred C., Lansing, Mich.
Lawrence, W. E., Agricultural College, Mich.
Leverett, Frank, Ann Arbor, Mich.
‡Lillie, Frank R., Chicago, Ill., Univ. of Chicago.
‡Litterer, Wm., Nashville, Tenn.
‡Loew, Fred A., Huntington, Ind.
Lombard, Warren P., Ann Arbor, Mich.
Lovejoy, P. S., Ann Arbor, Mich.
Lyons, Albert B., Detroit, Mich., 72 Brainard St.
MacCurdy, Hansford, Alma, Mich.
Magee, M. J., Sault Ste. Marie, Mich.
Magers, S. D., Ypsilanti, Mich.
*Manton, W. P., Detroit, Mich., 32 Adams St. W.
Marshall, Chas. E., Agricultural College, Mich.
Marston, T. F., Bay City, Mich.
Martin, Geo. W., Dayton, O., 1500 E. 5th St.
Mast, S. O., Holland, Mich.
Moxness, Dorothea, Agricultural College, Mich.
Mills, W. M., Battle Creek, Mich.
Murbach, Louis, Detroit, Mich., 950 Cass Ave.
Myers, Jesse J., Agricultural College, Mich.
‡Nattress, Thos., Rev., Amherstberg, Ontario, Can., St. Andrews Manse.
Nellist, John F., Grand Rapids, Mich.
*Newcombe, Fred C., Ann Arbor, Mich.
Newman, H. H., Ann Arbor, Mich.
Notestein, Frank N., Alma, Mich.
Novy, F. G., Ann Arbor, Mich.
Patten, A. J., Agricultural College, Mich.
Peet, Max M., Ypsilanti, Mich.
Pennington, L. H., Ann Arbor, Mich.
Pettee, Edith Ellen, Detroit, Mich., 83 Harper Ave.
Pettit, Rufus H., Agricultural College, Mich.
Phelps, Jessie, Ypsilanti, Mich., 49 N. Adams St.
Pierce, Ida, Battle Creek, Mich., 68 Frelinghysen Ave.
Pollock, J. B., Ann Arbor, Mich.
Praeger, Wm. E., Kalamazoo, Mich.
Reeves, Cora D., Manistee, Mich., 380 Third St.
Reighard, Jacob, Ann Arbor, Mich.
Robison, Floyd W., Agricultural College, Mich.
Roth, Gilbert, Ann Arbor, Mich.
Ruthven, A. G., Jr., Ann Arbor, Mich., 821 E. Ann St.
Sackett, Walter G., Agricultural College, Mich.
Sargent, Herbert E., Grand Rapids, Mich.
Seaman, A. E., Houghton, Mich.
Shaw, R. S., Agricultural College, Mich.
*Sherzer, Wm. H., Ypsilanti, Mich.
Shull, A. Franklin, Ann Arbor, Mich., 1017 Vaughan St.
Smith, Charles E., Pontiac, Mich., 108 N. Saginaw St.
Smith, Bertram, Ann Arbor, Mich.
‡Smith, Harlan I., New York, N. Y., 77th St., & Central Park.
*Spaulding, Volney M., Witch Creek, Cal.

Sperr, Fred M., Houghton, Mich., 107 Bubbell Ave., Box 277.
Stanton, Samuel McC., Ann Arbor, Mich.
*Sterns, Frances L., Adrian, Mich., 335 N. Prospect St.
Streng, Louis H., Grand Rapids, Mich.
*Strong, E. A., Ypsilanti, Mich.
‡Taylor, Frank B., Fort Wayne, Ind.
Thompson, Harriet W., Port Sanilac, Mich.
Trachsel, Wm. J., Lansing, Mich., 706 Ottawa W.
Transeau, E. N.
Vaughan, V. C., Ann Arbor, Mich.
Vaughan, V. C., Jr., Detroit, Mich., 1939 Woodward Ave.
Von Rosenburg, Albert, Lansing, Mich., 729 E. Shiawassee St.
Walker, Bryant, Detroit, Mich., 18 Moffat Bldg.
Wallace, Wm. T., Hastings, Mich.
‡Ward, Henry B., Lincoln, Neb.
Wetmore, Mary, Agricultural College, Mich.
‡Wheeler, Chas. F., Washington, D. C., Bureau of Plant Industry.
*Wheeler, E. S., Detroit, Mich., Jones Building.
Whitney, M. L., Saginaw, Mich., 108 Owen St.
Whittaker, Clive Chas., Orchard Lake, Mich., Mich. Military Academy.
Williams, Gardner S., Ann Arbor, Mich..
*Willson, Mortimer, Port Huron, Mich., Sixth & Water Sts.
Wilson, Wm., Coldwater, Mich.
Wood, L. H., Ann Arbor, Mich.
Wood, Norman A., Ann Arbor, Mich., 1216 S. Univ. Ave.
‡Wolcott, Robt. H., Lincoln, Neb.
Wright, L. L., Ironwood, Mich.
‡Wright, Winifred R., Stillwater, Okla.
Wyman, Thos. B., Negaunee, Mich.

MICHIGAN ACADEMY OF SCIENCE EXCHANGES.

Academia de Ciencias y Artes, Barcelona, Spain.
Academia de Ciencas Médicas, Havana, Cuba.
Academia de Ciencias naturales, Lima, Peru.
Academia des sciences de Cracovie, Krakau, Austria-Hungary.
Academia Mexicana de ciencias Exactas, Mexico.
Academia national de ciencias ec Cordobo, Cordoco, South America.
Academia polytechnica do Porto, Oporto, Portugal.
Academia real des sciencias, Lisbon, Portugal.
Accademia delle scienze, Genoa, Italy.
Accedemia delle scienze dell'institutio de Bologna, Bologna, Italy.
Academie de la Rochelle, La Rochelle, France.
Academie de Metz, Metz, Loraine, France.
Academie des sciences, Dijon, France.
Academie des sciences, Lyons, France.
Academie des sciences, Montpellier, France.
Academie des sciences, Rouen, France.
Academie des sciences, Toulouse, France.
Academie des sciences et Belles-lettres, Toulouse, France.
Academie national des sciences, Caen, France.
Académie royale Suédoise des sciences, Stockholm, Sweden.
Academy of natural sciences of Philadelphia, Phila., Pa.
Adrian public school library, Adrian, Mich.,
Adrian scientific society, Adrian, Michigan.
Alabama Geological Survey, University, Alabama.
Albion college, Albion, Michigan.
Alma college library, Alma, Michigan.
Alpena public library, Alpena, Michigan.
American academy of arts and sciences, Boston, Mass.
American association for the advancement of science, Washington, D. C.
American electro-therapeutic association, N. Y.
American entomological society, Phila., Pa.
American geographical society, N. Y.
American geologist, Minneapolis, Minn.
American gynecological society, N. Y. City.
American laryngological association, N. Y. City.
American laryngological, rhinological and otological society, N. Y.
American monthly microscopical journal, Washington, D. C.
American museum of natural history, N. Y. City.
American philosophical society, Philadelphia, Pa.
Ann Arbor public library, Ann Arbor, Michigan.
Archives des sciences physiques et naturelles, Geneva, Switzerland.
Asiatic society of Bengal, Calcutta, India.
Astronomical and physical society, Toronto, Ontario.
Astronomical society of the Pacific, San Francisco, Calif.
Atlanta University, Atlanta, Georgia.

Badischer botanischer verein, Freiburg im Breisgan, Germany.
Bay City public library, Bay City, Michigan.
Bayerische botanische gesellschraft, Munich, Germany.
Baylor university, Waco, Texas.
Berliner entomologischer verein, Berlin, Germany.
Besancon University library, Besancon, France.
Biblioteca nazionale central, Florence, Italy.
Bibliotheca da faculdad de direto do Recife, Bernambuco, Brazil.
Bibliothek nacional, Buenos Aires, Argentine Republic.
Biblogiska Förenig, Stockholm, Sweden.
Birmingham school board, Birmingham, England.
Birmingham university, Birmingham, England.
Bombay university, Bombay, India.
Boston public library, Boston, Mass.
Boston medical library, Boston, Mass.
Boston scientific society, Boston, Mass.
Boston society of natural history, Boston, Mass.
Boston zoological society, Boston, Mass.
Botanical gardens, Kingston, Jamaica.
Botanical society, Edinburgh, Scotland.
Botanischer verein, Landshut, Germany.
Botanischer verein der Brandenburg, Berlin, Germany.
Brighton & Hove natural history and philosophical society, Brighton, England.
Bristol naturalists' society, Bristol, England.
British association for the advancement of science, Burlington House, London, England.
British association for the advancement of science, Montreal, Quebec.
Brookville society of natural history, Brookville, Indiana.
Budapest Kir magy termeszettudomangi tarsulot, Budapest.
Buffalo society of natural sciences, Buffalo, N. Y.
California academy of sciences, San Francisco, Calif.
Calumet public library, Calumet, Michigan.
Cambridge philosophical society, Cambridge, England.
Canada geological and natural history survey, Ottawa, Canada.
Canadian archives, Ottawa, Canada.
Canadian entomological society, London, England.
Canadian Institute, Toronto, Canada.
Central state normal, Mt. Pleasant, Michigan.
Chicago academy of sciences, Chicago, Ill.
Cincinnati society of natural history, Cincinnati, Ohio.
College of Physicians, Philadelphia, Pa.
Colorado college, Colorado Springs, Colo.
Colorado scientific society, Denver, Colo.
Comite geologique a l'institut des mines, St. Petersburg, Russia.
Commerzbibliothek, Hamburg, Germany.
Commissao geofraphica e geologica, Sao Paulo, Brazil.
Concilium bibliographicum, Zurich Neumunster, Switzerland.
Connecticut academy of arts and sciences, New Haven, Conn.
Connecticut state library, Hartford, Conn.
Dalhousie college, Halifax, Nova Scotia.
Davenport academy of natural science, Davenport, Iowa.
Denison university of scientific laboratories, Granville, Ohio.

Denver university, Denver, Colo.
Detroit public library, Detroit, Michigan.
Deutsche botanischen gesellschaft, Berlin, Germany.
Deutsche geologische gesellschaft, Berlin, Germany.
Deutsche zoologische gesellschaft, Berlin, Germany.
Deutscher u. Oesterreischer Alpen-verein, Munchen, Germany.
Deutscher wissenschaftlicher verein, Santiago, Chili.
Ecolé normale supérieure, Paris, France.
Ecolé pratique des hautes études, Paris, France.
Edinburgh geological society, Edinburgh, Scotland.
Elgin scientific society, Elgin, Ill.
Elisha Mitchell scienfific society, Chapel Hill, N. C.
Elliot society of science and arts, Charleston, S. C.
Entomological society, London, England.
Entomological society, Oxford, England.
Entomological society of Canada, Quebec, Canada.
Entomologischer verein, Stettin, Germany.
Entomologiska foreningen i Stockholm, Stockholm, Sweden.
Essex institute, Salem, Mass.
Exeter natural history society, Exeter, New Hampshire.
Field museum of natural history, Chicago, Ill.
Finland geological commission, Helsingfors, Finland.
Folio bibliographica, Berlin, Germany.
Franklin & Marshall college, Lancaster, Pa.
Geographical society of Australia, Queensland Branch, Brisbane.
Geographical society of California, San Francisco, Calif.
Geographical society of Finland, Helsingfors,, Finland.
Geographical society of Philadelphia, Philadelphia, Pa.
Geographischer gesellschaft, Bremen, Germany.
Geographischer gesellschaft f. Thuringen, Jena, Germany.
Geological and natural history survey, Ottawa, Canada.
Geological commission, Helsingfors, Finland.
Geological society, Glasgow, Scotland.
Geological society, Manchester, England.
Geological society of South Africa, Johannesburg, South Africa.
Geological survey, Helsingfors, Finland.
Geological survey of Missouri, Jefferson City, Mo.
Geological survey of New Foundland, St. John's, N. F.
Geological survey of New Jersey, New Brunswick, N. J.
Den geologiska undersogelse, Christiana, Norway.
Georgia university, Athens, Georgia.
Glasgow school board, Glasgow, Scotland.
Grand Rapids public library, Grand Rapids, Michigan.
Gray Herbarium of Harvard University, Cambridge, Mass.
Greifswald geographische gesellschaft, Greifswald, Germany.
Harvard museum of comparative zoology, Cambridge, Mass.
Hillsdale college library, Hillsdale, Michigan.
Historical and scientific society, Washington, D. C.
Hull literary and philosophical society, Hull, England.
Hungarian geological society, Budapest, Hungary.
Illinois geological survey, Urbana, Ill.
Illinois state laboratory of natural history, Urbana, Ill.
Illinois state museum of natural history, Springfield, Ill.

Imperial mineralogical society, St. Petersburg, Russia.
Indiana academy of science, Indianapolis, Ind.
Indiana geological survey, Indianapolis, Ind.
Institut Grand Ducal de Luxembourg, Lux, France.
Institute od Jamaica, Kingston, Jamaica.
Instituto historico geographico, Rio de Janeiro, Brazil.
Instuto scientifico della R. Universita, Rome, Italy.
Institution of civil engineers, London, England.
Instituto geologico de Mexico, Mexico.
Ionia Hall Fowler memorial library, Ionia, Michigan.
Iowa academy of sciences, Des Moines, Iowa.
Iowa geological survey, Des Moines, Iowa.
Iowa geological survey, T. E. Savage, Des Moines, Iowa.
Iron Mountain Carnegie library, Iron Mountain, Michigan.
Jackson public library, Jackson, Michigan.
Jenaische zeitschrift f. medizin u. naturwissenschaften, Jena, Germany.
John Crerar library, Chicago, Ill.
K. Bohmische gesellschaft d. wissenschaft, Prag, Bohemia.
K. K. geographische gesellschaft, Wien, Austria-Hungary.
K. K. geologische reichanstalt, Wien, Austria-Hungary.
K. K. zoologisch-botanische gesellschaft, Wien, Austria.
K. Zoologische genootschap "natura artis magistra," Amsterdam, Netherlands.
Kaiserliche Leopoldinisch-Carolinische deutsche academie, Halle-an-der-Saa le, Germany.
Kansas academy of science, Topeka, Kansas.
Kansas university geological survey, Lawrence, Kansas.
Koniglich botanischer gesellschaft in Regensburg, Regensburg, Bavaria.
N. Krichtafovich, New Alexandria, Russia.
Laval university, Quebec, Canada.
Linnaean scientific and historical society, Lancaster, Pa.
Linnaenan society, Burlington House, London, England.
Linnaean society of New South Wales, Sidney, N. S. W.
Liverpool geological association, Liverpool, England.
Liverpool geological society, Liverpool, England.
London entomological and natural history society, London, England.
London school board, London, England.
Manitoba historical and scientific society Winnipeg, Manitoba.
Manitoba university, Winnipeg, Manitoba.
Marine biological laboratory, Back Bay, Boston, Mass.
Maryland geological survey, Baltimore, Md.
Mass. Horticultural society, Boston, Mass.
Medicinische naturwissenschaftliche section Siebenburgischen museum vereins, Klausenburg, Austria.
Melbourne Government botanist, Melbourne, Victoria, Australia.
Michigan agricultural college, Agricultural College, Michigan.
Michigan college of mines library, Houghton, Michigan.
Michigan state normal, Ypsilanti, Michigan.
Michigan state normal, Marquette, Michigan.
Minnesota academy of natural sciences, Minneapolis, Minn.
Missouri botanical garden, St. Louis, Mo.
Missouri bureau of geology and mines, Rolla, Mo.
Museo civico di storia naturali, Triesta, Austria.

Museo nacional de Buenos Aires, Buenos Aires, So. America.
Museo nacional de Montevideo, Uruguay.
Museu Paraense de historia natural, Para, Brazil.
Museum nacional Montevideo, Uruguay.
Museum of geology and archaeology, Princeton, N. J.
Muskegon Hackley public library, Muskegon, Michigan.
National academy of science, Washington, D. C.
Natural history and philosophical society, Belfast, Ireland.
Natural history society, Aberdeen, Scotland.
Natural history society, Bombay, India.
Natural history society, Glasgow, Scotland.
Natural history society of Montreal, Montreal, Canada.
Natural history society of New Brunswick, St. Johns, N. B.
Natural history society of Northumberland, Newcastle-upon-Tyne, Eng.
Natural science association of Staten Island, New Brighton, N. Y.
Naturforschende gesellschaft, Bamberg, Germany.
Naturforschende gesellschaft in Basel, Basel, Switzerland.
Naturforschende gesellschaft in Berne, Berne, Switzerland.
Naturforschende verein in Brunn, Brunn, Austria.
Naturforschende gesellschaft, Gorlitz, Saxony, Germany.
Naturforschende gesellschaft, Zurich, Switzerland.
Naturhistorische gesellschaft zu Hannover, Hannover, Prussia.
Naturhistorische gesellschaft, Nurnberg, Bavaria.
Naturhistorisch-medicinischer verein, Heidelberg, Germany.
Naturwissenschaftliche gesellschaft, Chemnitz, Saxony.
Naturwissenschaftlicher verein, Augsburg, Germany.
Naturwissenschaftlicher verein, Bremen, Germany.
Naturwissenschaftlicher verein, Frankfurt-an-der-Oder, Prussia.
Naturwissenschaftlicher verein, Karlsruhe, Germany.
Naturwissenschaftlicher verein, Luneburg, Germany.
Naturwissenschaftlicher verein, Magdeburg, Germany.
Naturwissenschaftlicher verein, Osnabruch, Germany.
Naturwissenschaftlicher verein, Hamburg, Germany.
Naturwissenschaftlicher verein, Halle-an-der-Salle, Germany.
Naturwissenschaftlicher verein, Keil, Prussia.
Naturwissenschaftlicher verein, Regensburg, Bavaria.
Nederlandsche entomologische vereins, Leiden, Holland.
New Orleans academy of science, New Orleans, La.
New South Wales Dept. of mines and agriculture, Sidney, N. S. W.
N. Y. academy of medicine, N. Y.
New York botanical gardens, N. Y. City.
New York microscopical society, Flatbush, L. I., N. Y.
New York public library, N. Y.
New York state library, Albany, N. Y.
New York state museum of natural history, Albany, N. Y.
New Zealand geological survey, Wellington, N. Z.
Newark entomological society, Newark, New Jersey.
Niederoesterreichischer reichs-forst-verein, Wien, Austria.
North Carolina geological survey, Raleigh, N. C.
North Dakota experiment station, Agri. College, Fargo, N. D.
Northampton institute, St. Johns street road, London.
Nova Scotian institute of science, Halifax, Nova Scotia.
Nurnberg naturhistorische gesellschaft, Nurnberg, Germany.

Oahu college, Honolulu, Hawaii.
Oberhessische gesellschafy f. natur. u. heilkunde, Giessen, Germany.
Oberlin college library, Oberlin, Ohio.
Oesterreicher reichs-forst-verein, Wien, Austria.
Ohio academy of sciences, Columbus, Ohio.
Ohio state archaeol. and historical society, Columbus, Ohio.
Ohio state university, Columbus, Ohio.
Ohio Wesleyan university, Delaware, Ohio.
Olivet college, Olivet, Michigan.
Ornithologische gesellschaft, Budapest, Hungary.
Ottawa literary and scientific society, Ottawa, Canada.
Peabody academy of science, Salem, Mass.
Peabody institute library, Baltimore, Md.
Peabody museum of American archaeol. and ethnology, Cambridge, Mass.
Pennsylvania geological survey, Phila., Pa.
Petoskey public library, Petoskey, Michigan.
Phillips Exeter academy, Dept. of archaeology, Andover, Mass.
Philosophical society, Glasgow, Scotland.
Popular Science Monthly, Sub-station 84, N. Y.
Portland society of natural history, Portland, Maine.
Princeton academy of science, Princeton, Ill.
Quebec geographical society, Quebec, Canada.
Queen's college, Belfast, Ireland.
Queen's college, Galway, Ireland.
Queen's college and university, Kingston, Canada.
Real academia de ciencias de Madrid, Madrid, Spain.
R. Accademia delle scienze e belle lettere, Naples, Italy.
R. Accademia di science, Padua, Italy.
R. Accademia de scienze, Palermo, Italy.
R. Instituto Veneto de scienze, Venice, Italy.
Revista, Museu Paulista, St. Paulo, Brazil.
Revue geographique internationale, Paris, France.
Rivista Argentina, La Plata, So. America.
Rivista Italiana di scienze naturali, Siena, Italy.
Rochester academy of science, Rochester, N. Y.
Royal astronomical society of Canada, Toronto, Canada.
Royal botanic garden, Sibpur, Calcutta, India.
Royal botanic gardens, Kew, England.
Royal botanic society, Regents Park, London, England.
Royal Dublin society, Dublin, Ireland.
Royal geographical society, London, England.
Royal geographical society of Australasia, Adelaide, Australia.
Royal geological society of Cornwall, Penzance, England.
Royal Hungarian society of natural sciences, Budapest, Hungary.
Royal institute botanico, Palermo, Italy.
Royal Irish academy, Dublin, Ireland.
Royal London ophthalmic hospital, London, England.
Royal medical and chirurgical society, London, England.
Royal microscopical society, King's college, London, England.
Royal society of Canada, Montreal, Canada.
Royal society of Edinburgh, Edinburgh, Scotland.
Royal society of New South Wales, Sidney, N. S. W.

Royal society of Queensland, Brisbane, Australia.
Royal society of South Australia, Adelaide, So. Australia.
Royal society of Tasmania, Hobarton, Tasmania.
Royal society of Victoria, Melbourne, N. S. W.
Royal Swedish academy of sciences, Stockholm, Sweden.
Sage library, Bay City, Michigan.
Saginaw, E. Side, public library, Saginaw, Michigan.
St. Francis Xavier college, Antigonish, Nova Scotia.
Saint Gallische naturwissenschaftlicher gesellschaft, Saint-Gall, Switzerland.
St. Louis academy of science, St. Louis, Mo.
St. Paul academy of natural science, St. Paul, Minn.
San Diego society of natural history, San Diego, Calif.
School of Mines, Ballerat, Victoria, Australia.
Schweizerische entomologischer gesellschaft, Schaffhausen, Switzerland.
Schweizerischer forst-verein, Zurich, Switzerland.
Scientific society of Finland, Helsingfors, Finland.
Scientific society of Trinidad, Port of Spain, Trinidad.
Smithsonian institution, Washington, D. C.
Sociedad de ciencias fisicas y naturales, Caracas, Venezuela.
Sociedad cientifica "Antonio Alzate," Mexico.
Sociedad cientifica Argentina, Buenos Aires, Argentine Republic.
Sociedad de agricultura, Mexico.
Sociedad do geographia, Rio de Janeiro, Brazil.
Sociedad Mexicana de historia natural, Mexico.
Sociedad scientifica, S. Paulo, Brazil.
Societa Adriatica di scienza naturali, Triesta, Austria.
Societa entomologica Italiana, Florence, Italy.
Societa Italiana delle scienze, Rome, Italy.
Societa Italiana di naturali, Milan, Italy.
Societas pro fauna et flora fennica, Helsingfors, Finland.
Societa Toscana de scienza naturali, Pisa, Italy.
Société de biologie, Paris, France.
Société de botanique, Luxembourg, Lux, France.
Société de geographie de Toulouse, Toulouse, France.
Société de horticulture et de botanique, Marseilles, France.
Société des sciences, Le Harve, France.
Société des sciences, de Nancy, Nancy, France.
Société des sciences, Versailles, France.
Société des sciences, Strassburg, Germany.
Société des sciences, Auxerre, France.
Société des sciences historiques, Bastia, France.
Société des sciences naturelles, Neuchatel, Switzerland.
Société des sciences physiques et naturelles, Zurich, Switzerland.
Société Belge de géographie, Bruxelles, Belgium.
Société Belge de geologie, Bruxelles, Belgium.
Société entomologique de Belgique, Bruxelles, Belgium.
Société entomologique de France, Paris, France.
Société d'étude scientifiques de Lyon, Lyon, France.
Société geologique de Belge, Liege, Belgium.
Société geologique de France, Paris, France.
Société d'histoire naturelle, Autun, France.
Société imperiale des naturalistes de Moscow, Moscow, Russia.

Société Linneene de Bordeaux, Bordeaux, France.
Société Linneene de Lyon, Lyons, France.
Société Linneene de Normandie, Caen, France.
Société Linneene du Nord de la France, Amiens, France.
Société nationale des sciences naturelles, Cherbourg, France.
Société physico-mathematique de Kasan, Kasan, Russia.
Société royal des sciences, Liege, Belgium.
Société royal linneene de Bruxelles, Bruxelles, Belgium.
Société scientifique de Bruxelles, Bruxelles, Belgium.
Société scientifique de Chevtchenko, Lemberg, Austria.
Société scientifique du Chili, Santiago, Chili.
Société Zoologique de France, Paris, France.
Society of natural history, Boston, Mass.
South Dakota geological survey, Sioux Falls, S. D.
Spokane academy of sciences, Spokane, Washington.
Staten Island association of arts and sciences, New Brighton, N. Y.
Sydney university, Sydney, N. S. W.
Tacoma academy of science, Tacoma, Washington.
Texas academy of science, Austin, Texas.
Tokio Imperial museum, Dept. of natural history, Tokio, Japan.
Torrey botanical club, N. Y.
Traverse City public library, Traverse City, Michigan.
Trenton natural history society, Trenton, N. J.
Trinity university, Toronto, Canada.
U. S. dept. of agriculture, Washington, D. C.
U. S. geological survey, Boston, Mass.
U. S. geological survey, Washington, D. C.
U. S. naval observatory, Washington, D. C.
U. S. surgeon general's office library, Washington, D. C.
Universidad literaria de Zaragoza, Saragossa, Spain.
Universita commerciali, Milan, Italy.
Université Impériale, Moscow, Russia.
University college, Auckland, New Zealand.
University of Mexico, Mexico.
University of Montana, Messoula, Montana.
University of Vermont, Burlington, Vt.
Verein f. geographie u. statistik, Frankfurt-am-Main, Prussia.
Verein fur naturkunde, Offenbach, Baden.
Verein fur naturwissenschaften, Braunschweig, Germany.
Verein zu verbreitung naturwissenschaftlicher kentnisse, Wien, Austria.
Victoria geological survey, Melbourne, Victoria.
Victoria university, Toronto, Canada.
Wagner free institute of science, Philadelphia, Pa.
Washington academy of science, Washington, D. C.
Washington anthropological society, Washington, D. C.
Washington philosophical society, Washington, D. C.
Western state normal school, Kalamazoo, Michigan.
Westfalische provinzial-verein d. wissenschaft, Munster, Germany.
Wisconsin academy of science, Madison, Wis.
Wisconsin natural history society, Milwaukee, Wis.
Worcester natural history society, Worcester, Mass.

Yale university, Forest school, New Haven, Conn.
Yale university observatory, New Haven, Conn.
Yorkshire geological and polytechnical society, Halifax, England.
Zoologischer anzeiger, Leipzig, Germany.
Zoological society, Philadelphia, Pa.

G. P. BURNS, Librarian.

ISRAEL COOK RUSSELL.

Since the last meeting of the Academy there has passed from among us one who had always been a leading and interested participant in the discussions concerning the welfare of our organization and its activities since its foundation.

Israel Cook Russell, the subject of this brief memorial, was not only known to the circle here, but as well, and possibly better, beyond these circumscribed limits, as a writer of great ability and authority upon his chosen subjects, as a scientific, thorough and careful student, as a daring explorer, and as a teacher who was constantly striving to give his students the best results of his own and others' work in geology and kindred subjects.

He was born near Garratsville, N. Y., on December 10, 1852, and was the son of Barnabas and Louisa Sherman (Cook) Russell, who were of New England descent, and moved with his parents when twelve years of age to Plainfield, N. J. His education followed the usual course; preparation for college, first, at a high school, near his home in New York State, and afterwards at the Hasbrook Institute, Jersey City, and a college course at the University of the city of New York, from which he was graduated with the degrees of A. B. and C. E., in 1872, after which he took a graduate course at the Columbia School of Mines.

His first scientific work after his college course was finished, was done in 1874, while he was attached to the U. S. Transit of Venus Expedition to New Zealand and Kerguelen Island, as photographer, acting, however, in the capacity of naturalist as well. It was doubtless on this expedition that he gained the experience in the art of photography which enabled him to do so much most excellent photographic work in his later explorations.

In 1876 he was appointed assistant professor of geology in the Columbia School of Mines, resigning in 1878 to accept a position with the U. S. Geographical survey west of the 100th meridian, and for a year, or more, was engaged in geological work in New Mexico. In 1880, after returning from a trip to Europe, he entered the United States Geological Survey and was assigned to the Division of the Great Basin, in which his special work eventually became the investigation of the Quarternary history of a series of desert basins in Northern Nevada, and adjacent parts of California and Oregon, and as the result of this work, he prepared a series of papers which are classics, and secured for him high praise in this country and in Europe.

After completion of this work he was assigned the investigation and mapping of portions of the Paleozoic formations in the southern Appalachian region, and later prepared a report upon the Newark formation. In 1889 he made his first trip to Alaska, ascending the Yukon River, and crossed the mountains southward to the Lynn Canal during the early part of winter. This work was done under the auspices of the U. S. Geological Survey in connection with the work of the U. S. Coast and Geodetic Survey, which was then surveying a portion of the eastern boundary of Alaska.

The next two summers were also spent in Alaska, exploring Mt. St. Elias and the adjacent region, and as a result of his studies upon the Malaspina glacier, his very valuable contributions to glacial geology were made. In

1892 he was elected Professor of Geology in the University of Michigan, in which position we learned to know and honor him. In 1886 he was married to Miss J. Augusta Olmstead, who, with three daughters and a son, survive him.

As compiled by Librarian Koch, of the University of Michigan, his list of published writings contains 124 numbers, and there were five unpublished, but completed, or nearly finished, manuscripts upon his desk at the time of his death, two at least of which will be published. Seven of his published productions are books, and of his remaining publications 30 may be classed as extensive reports of investigations, or major scientific papers, and 50 as brief discussions and minor contributions to our knowledge of the subjects in which he was interested. The rest of the list is made up of miscellaneous papers, a considerable proportion of which may be termed educational and philosophic.

Among the books already mentioned, there are several valuable works which were in part, at least, the outgrowth of his work as a teacher. These are what he modestly termed "Reading Books," but in reality they are monographic manuals adapted to the needs of the general reader, or student, in which not only all the data collected by others have been brought together in a single volume, but the results of the wide personal investigations and observations of the writer are given, and the light of his analysis of facts and theories is added. This makes these works useful to the expert, as well as valuable and available to the beginner, and they are not infrequently quoted as standard authority.

In these works his style is simple, direct and pleasing, a statement equally applicable to all of his publications; there is very little technical language used, and such as there is, is not difficult to grasp. These writings also abound in illustrative matter and descriptions of actual localities which are considered typical, enliven and enrich the text with word pictures which take the reader to the place described, and point out the salient features to be observed, and explain their meaning.

This habit of making his writings clear and interesting was a fixed one, and pervaded his more technical works as well as the group under discussion. One instance in point, is to be found in the monographic study of the Mono Lake region of California. This region has recently been made accessible by rail, and a demand came from the people living in the county in which the lake lies to the Director of the U. S. Geological Survey for a new edition of the report, to be paid for by the residents, who were to use it in attracting the attention of tourists and others to the wonders of the lake and the surrounding country. The request of the committee in charge of the matter explicitly stated that the attractive style in which the report was written made it very desirable for their purpose. It was to revise his work of twenty years ago in that region that the summer of 1906 was to be devoted. In passing it may be said that this pleasing and attractive style in no way detracted from the *scientific* value of his work, and was cultivated with the express hope that it might make it of more use to a larger number of people—a hope which in this case was undoubtedly realized.

Of a slightly different class from the "Reading Books," is the book entitled "North America in 1900," published in the series "The world in 1900." This is a popular resumé of the Physical Geography of the North American Continent and its condition at the beginning of the 20th century, and is an excellent reference work on the subject.

Among other works which are of a distinctly educational type are two "Geographic Monographs," a part of a series, written to aid teachers and furnish collateral reading for students of geology and physical geography in secondary schools. With these also should be placed a paper on the Topographic Atlas of the U. S., which shows the uses which may be made of this magnificent series of maps by various classes. Along this same line also is the address delivered before the Michigan Academy of Science as its President in 1894, upon the topographic survey of Michigan, in obtaining which he was greatly instrumental, by making a strong plea showing how generally useful such a survey with its resulting maps would be to all classes, pointing out especially the educational value of the completed work.

His major contributions to the sum of human knowledge are along the lines of Physical Geography, Descriptive Geology and Dynamic Geology, and, although much of his work of investigation was of reconnaisance or exploratory character, it was done thoroughly and so well that those who follow him will find little that is new.

His observations were carefully made, and fully and clearly described, and, since he was a tireless worker in his study as well as in the field, promptly published. It was his habit to begin writing the account of his season's field work immediately upon his return home, while the details were still fresh in mind, and it was this industry which gave us the last two works which he finished, his report of the surface geology of the Menominee region in the Northern Peninsula, and the paper which he was to have read before the Geological Society of America.

A very few of his briefer papers are reviews, and he seems to have indulged in controversial writings to but a slight extent. Two things stand out prominently in all of his written work, first, thoroughness and careful attention to important details, and second, clearness of statement, accompanied by abundant illustration both by verbal and by actual pictures, so that even laymen could find much of interest in the most technical of his papers.

While Professor Russell was a deep thinker upon the problems pertaining to many of the lines of research in his chosen field of work, there is little of the purely speculative in his published writings, and apparently he kept his imagination well in hand in developing hypotheses to account for observed facts, working out those which were reasonable and probable. He was persistent and patient in gathering facts, and his statement of them may be relied upon, as he made little, if any, use of hearsay statements; his mind was flexible and active, when he was making observations, and he was quick to see the bearings of *new* observations, and to place them in their proper categories and did not hesitate to discard an old theory when it did not fitly explain newly-observed facts.

Little has been said of his work as a geographer, but this was fully as important as his geological work. His love for penetrating the unknown and difficult parts of the continent was well known to all of his intimate friends, and it was a cherished hope that he might again have the opportunity to go to Alaska to explore some of the more inaccessible portions of its mountain fastnesses.

In all of his field work after his connection with the University of Michigan he was constantly on the lookout for illustrative material, with which to enrich his lecture courses, and a large number of unique specimens were added to the geological collections as the result of this activity, as well as many photographs and lantern slides, which could not have been obtained in any

other way. His skill as a photographer was unusual, and he possessed rare ability in choosing proper subjects, and the right light and angle to show these in order to make the most attractive pictures, as well as to illustrate the point under consideration. He not only had the skill which comes from long practice, but a love for the beautiful and the artistic instinct as well.

He was a member of several scientific and professional societies, and had served this Academy as President and as Vice President of the Section of Geology, and in many ways less formally. In the broader fields, he had been Vice President of the American Association for the Advancement of Science, and was President of the Geological Society of America when he died, and his last completed writing was a paper entitled "Concentration as a Geological Principle," intended to be used as his presidential address to the society at the annual meeting. He held the honorary degree of Doctor of Laws, given him both by his alma mater and the University of Wisconsin.

The writer had the pleasure and good fortune to be associated with Professor Russell during his field work in the Menominee region in 1905, the last of his life, and thus had a chance to become somewhat closely acquainted with his methods of work, and to strengthen a bond of friendship already formed. In the intimate associations of camp life his steadfastness of purpose, his simplicity of character, serenity of spirit, his goodness of heart and consideration for his associates were deeply impressed upon the writer's mind. It is entirely characteristic of the man that while he was a delightful story-teller, he rarely volunteered to tell of his experiences, and when urged to describe some of his adventures, declared that he had never had any, "for nothing had really ever happened to him." His love of home and his family was also a marked characteristic, and it was apparent from chance remarks that they were never absent from his mind during the entire season.

In person he was slightly below medium height, and of rather slender frame, so that he seemed almost frail, but really possessed great strength, agility and endurance, as must be apparent if his work as explorer is considered.

As a man, he was upright, generous, industrious, and always ready to do his whole duty as he saw it; and as a citizen, when called upon, was willing to give liberally and without cost of his time, energy and knowledge for the benefit of the community. This is exemplified in his voluntary services to the city of Ann Arbor as a member of the committee to investigate the city water supply, and his report on the subject is a most valuable one to the city.

Truly, a good man has gone from our midst, in the prime of a busy and useful life.

Chas. A. Davis,
University of Michigan, Ann Arbor, Michigan.

LIST OF PAPERS PRESENTED AT THE THIRTEENTH ANNUAL MEETING OF THE MICHIGAN ACADEMY OF SCIENCE.

Address by President James B. Pollock: "Some Physiological Variations of Plants and their General Significance."

Public Address by Prof. Wm. B. Hobbs: "Earthquakes viewed in a New Light."

1. Studies on the Relation of Woody Fungi to hosts in the Northern Peninsula of Michigan, L. H. Pennington, Ann Arbor.
2. Additions to the Flora of Michigan, W. J. Beal, Agricultural College.
3. The Flora of Marquette county in the Vicinity of Marquette, A. Dachnowski, Orchard Lake.
4. The Life History of Puccinea malvacearum, ten minutes, J. B. Dandeno, Agricultural College.
5. Ecological Notes from Leelanaw County, Illustrated, W. E. Praeger, Kalamazoo.
6. Vegetative Reproduction of Erythronium Americanum, ten minutes, J. B. Dandeno, Agricultural College.
7. Seasonal Variations in the Edaphic Conditions in Peat Bogs in the Vicinity of Ann Arbor, G. P. Burns, Ann Arbor.
8. A Botanical Terra Incognita In and Around Ann Arbor, twenty minutes, S. Alexander, Ann Arbor.
9. Notes on the Black Knot of Plum, etc., (Plowrightia morbosa), ten minutes, J. B. Dandeno, Agricultural College.
10. Crataegus in Southern Michigan, C. S. Sargent, Arnold Arboretum, Jamaica Plain, Mass., Presented by C. K. Dodge, Port Huron.
11. St. Clair County and its Flora, C. K. Dodge, Port Huron.
12. Unreported Michigan Fungi, C. H. Kaufman, Ann Arbor.
13. Michigan Characeæ, E. B. Bach, Ann Arbor.
14. The Flora of Southwestern Michigan, Its Special Features and Ecological Peculiarities, Illustrated, H. S. Pepoon, Chicago, Ill.
15. A Nectria fruiting upon earth and associated with a Fusarium causing Damping off in Seedlings, P. S. Lovejoy, Ann Arbor.
16. Can Fungi Assimilate Carbon Dioxid? J. B. Pollock, Ann Arbor.
17. The Bud Scales of Celastrus Aid the Vine in Climbing, W. J. Beal, Agricultural College.
18. Phyllody of the Stamens and Petals of Nymphaea (Nuphar) advena, W. J. Beal, Agricultural College.
19. Notes on the Distribution of Acer spicatum and Acer Pennsylvanicum, C. A. Davis, Ann Arbor.
20. Plant Societies of the Huron Mountains, C. A. Davis, Ann Arbor.
21. Geology and Physical Geography, W. F. Cooper, Lansing.
22. A Remarkable Coral Horizon in the Monroe Formation of Southern Michigan.
    Stratigraphic relations and occurrence, W. H. Sherzer.
    Palaeontology, A. W. Grabau.

23. Geologic Features shown on the topographic sheets of Southwestern Michigan, Frank Leverett, Ann Arbor.
24. Extent of the several drift sheets bordering the Driftless Area of the upper Mississippi Region, Frank Leverett, Ann Arbor.
25. The Geological Continuity of Essex County, Ontario, with Wayne and Monroe Counties, Michigan, Rev. Andrew Nattress, Amherstburg, Ont.
26. The Geology of the Chemistry of Waters, A. C. Lane, Lansing.
27. The Bearing of Recent Studies of Earthquakes Upon Fundamental Theories in Geology, Wm. H. Hobbs, Ann Arbor.
28. The Rainfall of the Great Lake Region, Mark S. W. Jefferson, Ypsilanti.
29. Some Interesting Glacial Phenomena in the Marquette Region, C. A. Davis, Ann Arbor.
30. Preliminary List of the Sites of Aboriginal Remains in Michigan, Harlan I. Smith, New York.
31. Behavior of Rabic Virus in Collodium Sacs, J. G. Cumming, Ann Arbor.
32. Behavior of Rabic Virus to Heat and Carbonic Acid, J. G. Cumming, Ann Arbor.
33. The Cultivation of Spirillum Obermeieri in Collodium Sacs, R. E. Knapp, Ann Arbor.
34. Whey and Ordinary Agar for Counting Milk Bacteria, Bell Farrand, Agricultural College.
35. Influence of Temperature Upon the Vigor of Lactic Cultures, C. E. Marshall and Louise Rademacher, Agricultural College.
36. The Significance and Control of Starters Employed in Ripening Cream and Milk, L. D. Bushnell, Agricultural College.
37. Protective and Curative Artificial Immunity Based on the Theory of Opsonins, A. P. Ohlmacher, Detroit.
38. Bacteriologlcal Study of a Case of Meat Poisoning, R. W. G. Owen, Ann Arbor.
39. Proteid Poisons, V. C. Vaughan, Ann Arbor.
40. Formicaldehyde Disinfection by means of Potassium Permanganate, E. M. Houghton and L. T. Clark, Detroit.
41. The Influence of the Composition of the Medium Upon the Solvent Action of Certain Soil Bacteria, C. W. Brown, Agricultural College.
42. Solvent Action of Certain Bacteria on Insoluble Phosphates, W. G. Sackett, and A. J. Patten, Agricultural College.
43. Human Physiology in the Grades, Charles W. Mickers, Adrian.
44. Human Physiology in the High School, Miss Grace Frances Ellis, Central High School, Grand Rapids.
45. Human Physiology in the High Schools, S. D. Magers, State Normal College, Ypsilanti.
46. Methods in Plant Physiology—Light as a Formative Influence, Alfred Dachnowski, Orchard Lake.
47. An automatic Aerating Device for Aquaria in Class Room, L. Murbach, Central High School, Detroit.
48. An Easy Method of Preparing Histological Sections of Bones, S. D. Magers, Ypsilanti.
49. Certain Septa-forming Ancyli, Bryant Walker.
50. Adaptation and Warning Color in Certain Tropical Marine Fishes, Jacob Reighard.
51. Spawning Behavior and Sexual Dimorphism in Fundulus heteroclitus and allied fish, H. H. Newman.
52. The Breeding Habits of Etheostoma, Miss Cora Reeves.

53. Breeding Habits of Amblystoma punctatum, B. G. Smith.
54. Notes on the Fall Migration of 1906, Norman A. Wood.
55. Trial and Error Movements in the White Rat, O. C. Glaser.
56. Museum Methods in Operation at the University Museum, F. S. Hall.
57. Movement and Problem Solving in Ophiura brevispina, O. C. Glaser.
58. Habits of Blarina brevicauda, the Short-tailed Shrew, Franklin Shull.
59. Stridulation of the Snowy Tree Cricket, Franklin Shull.
60. Some Changes in the Michigan Bird List, W. B. Barrows.
61. The Fall Migration of Birds on Isle Royale, Max M. Peet.
62. A collection of Reptiles from Southern New Mexico and Arizona, A. G. Ruthven.
63. Water Systems in Plants, J. B. Dandeno.
64. An Experiment to Show Whether Bumble Bees are necessary to Pollenize Red Clover, W. J. Beal.
65. Notes on Pure Food investigations, Floyd W. Robison.
66. Bounties for Harmful Animals, Walter B. Barrows.

SOME PHYSIOLOGICAL VARIATIONS OF PLANTS AND THEIR GENERAL SIGNIFICANCE.

JAMES B. POLLOCK.

In a survey of the domain of the biological sciences in recent years, one of the most significant facts is found in the extent to which physiology has invaded those fields of this domain which, in the earlier stages of development seemed entirely apart from and independent of physiological relations. When species of plants were supposed to have been created at the beginning just as we find them today, and to transmit their original characters unchanged to their remotest possible descendants, there was no physiological question as to the variations within species, and none as to the relation of species to each other nor as to the origin of new species. In that view there could be no origin of new species. They were all created at the beginning, and then the Creator rested.

When botany first began to be a science it was merely an attempt to classify plants, that is, to discover the characters of species as they were originally created, to group together those that were most alike and to separate those that were unlike. The characters used in the first attempts at classification were more or less superficial, and systematic botany was merely a study in formal external morphology.

But a change has come; and this change began with the general acceptance, among biologists, of the view that species are not entities with *necessarily fixed characters.* Even though *some* species of plants have persisted with constant characters ever since their earliest records were inscribed upon the rocks, no biological theory has received more certain confirmation in recent work than the theory that species are even now in process of creation. The creative power is not resting, never has rested. Species are appearing before our eyes. We have only to open them and see. In short, nature has been caught in the act of originating new species.

I refer of course to the work of de Vries, who has found among the evening primroses species which, every year, are giving rise to forms among their offspring sufficiently different from their immediate parents to be regarded as elementary species. With some of these new forms the characters which distinguish them from their parents are constant when propagated by seed. This is not to be regarded as the inheritance of characters acquired by the parents of these new elementary species, but rather as the appearance of new characters in the race, not by a gradual modification of parental characters, but by a sudden transformation to which de Vries has given the name *mutation.* These new characters cannot be ascribed to the direct influence of external factors on the adult or developing forms in which the new characters appear, since they appear and persist in the same conditions of life in which the parental type is continued. De Vries offers no explanation as to how these new characters are produced, but following his work, Mac Dougal has succeeded in producing new modifications by artificial means, using as a subject of his experiments species which are closely related to those with which de Vries obtained his notable results. Mac Dougal in-

jected various substances, radium preparations, sugar solutions, calcium nitrate, and zinc sulphate, into the capsules of the plants experimented upon, before the eggs were fertilized by the nuclei from the pollen grain. From the many capsules used, a few furnished seeds which, on planting, produced plants notably different from the type of the parent plant. The flowers of the new type were closely guarded to prevent cross fertilization, and their seeds when planted gave a few plants which conformed in every particular to the new type.

If there is no mistake about Mac Dougal's results, and I see no reason for supposing there is, at least one very important conclusion seems to be well founded, namely, that in an early stage of development of the plant egg, before it has been fertilized, it may be so profoundly modified that the adult plant resulting from it is decidedly different from what it would have been had the egg not been so modified, and the modifications thus produced are transmitted to the next generation through the seeds. Taking the results of both de Vries and Mac Dougal, we may conclude that the necessary modification of the egg is sometimes produced in nature, and may also be induced by means under the control of the experimenter.

There is one question which will probably be both affirmed and denied by different biologists for some time in the future. It is this: Are the new types which appear by sudden leaps to be considered new species or only varieties of the parent species. The debate on this question will be all the more acrid and prolonged because of the impossibility of giving a satisfactory definition of the term species.

One ought to ask pardon perhaps for quoting *authority* in science, but a high botanical authority has said that he believes no better definition of species has ever been invented than this: "A species is a perennial succession of like individuals." An equally high botanical authority has said that a species is a judgment. And this also is true. Species and other categories of classification are more or less arbitrary distinctions, made for convenience in classification of our knowledge. Hence in a given case, the question whether two different forms are to be regarded as two different species or not, is in part a matter of individual judgment. If Darwin's view is correct that new species may originate by the gradual accumulation of exceedingly minute differences, there could be no line of demarkation between species provided we could have all the transitional forms. Only where the transitional forms had disappeared, or the new forms had migrated to a new region, could we have sharp lines of distinction between species. Even in the case where the new form had migrated to a region not occupied by the old, the transitional forms would be disclosed on studying the species in all its range. Distinctions of species in such a case must necessarily be more or less a conventional matter. But if species originate by the sudden production of entirely new characters, that is by mutations, as de Vries believes, then there are no transitional forms connecting the new to the old. The condition in nature in this case would be similar to that in which there has been an extinction of the transitional forms between two different types derived from a common ancestor by gradual modifications. In either case there is room for individual judgment in the delimitation of species, according as the differences between the two types are greater or smaller. We say, "A species is a perennial succession of like individuals." But how nearly alike must they be. No two individuals are exactly alike, and the extreme differences possible between two individuals of the same species may be greater than those between two individuals of different species. In other

words, the differences within the species may be greater than the differences between species, as de Vries has pointed out. How then are we to decide whether two individuals comparatively different from each other, and yet alike, belong to the same or different species? It has been found that for any given character the variations within the species may be expressed numerically by an average with deviations, both above and below that average. For instance the average height of the stem in a given species of plants may be two feet. Most of the plants composing the species may vary only slightly from this average, say from one to three feet. But the greater the number of individuals examined and measured, the more certain it becomes that we shall find a few individuals which differ far more widely from the average. In our supposed case we might find that the extreme limits of size were six inches to ten feet, while the average was only two feet. These deviations from the average of the species are called the fluctuating variations. They are largely determined by the external conditions in which the species grows. Prof. George Klebs has shown that when plants are subjected to extremes of variation in the external conditions of light, heat, moisture, and food supply, the deviations from the average of the fluctuating variations become far greater than are usually found in a state of nature. Klebs' results with Semper vivum were truly remarkable. He produced variations that are not found in a state of nature in the species with which he worked, changes in the color, size and shape of the flower, great variations in length of the stem and its mode of branching, the size, shape and arrangement of the leaves. As the result of this kind of work, carried on for a considerable number of years, Klebs has given us a definition of a species which expresses the dependence of the form of the plant upon the environment. According to Klebs we must say:

"To a species belong all individuals which, propagated vegetatively or by self-fertilization, under like external conditions, show the same characters through many generations." If two plants under these conditions show a noticeable difference, they are to be regarded as belonging to two species, even though they have descended from a common ancestor. Gaston Bonnier has shown by experiment that plants transplanted from the region of Fountainebleau, near Paris, to Toulon, in the Mediterranean region, show in a few years adaptations both of external form and internal structure which cause them to resemble the species characteristic for the Mediterranean region. The same investigator found similar results on transplanting from the plains to the Alpine regions. Knowing the origin of such widely variant forms we do not call them two species, but merely extremes in the fluctuating variations of the species. It is conceivable, however, that nature might perform this same experiment on such a scale, and in such ways as to make it difficult or impossible to recognize the common origin of two such different types. In that case the botanical collector or systematist, finding the two types in widely separated regions, would describe them as two species of plants. If the distribution of the species was continuous from one of these extreme regions to the other the connecting intermediate forms would show that we had to do merely with extreme fluctuating variations brought about by extremes in soil, moisture, heat and light. If, however, the geographical continuity of the species had been interrupted in any way, it would be impossible to determine by observation alone that the two extreme types were only fluctuating variations of one species. That could be determined by the experimental method as followed by Klebs and Bonnier. Plant the two types in the same region, grow them under exactly the same conditions,

and if after many generations they continue to exhibit constant differences they are to be regarded as two species. On the contrary if they show the same characters under the same conditions, they are one species. Such a method of determining whether one has a new species or not involves an enormous amount of labor, and a great deal of time. It is not in favor with the systematists who work with the higher plants. Nevertheless there is an increasing recognition among botanists of the necessity of physiological work even in those fields of research that have in the past been dominated by morphology alone.

Such experiments might help to decide the question whether the so-called alpine species have been constant since the glacial period, as de Vries supposes they must have been, or whether, as seems possible, similar combinations of climatic conditions, operating in widely separated regions such as the alpine region of central Europe and the high latitude of Norway, have produced species of similar form. It does not even seem necessary to assume that the parent species of the alpine form has been the same in these widely separated regions. De Vries has pointed out that species sometimes over-lap by what he calls *transgression variations*. Klebs has shown that in one species of Sempervivum he could produce nearly all the characters found in the other species of the genus. Is it not therefore possible that the continuation of conditions of soil, temperature, moisture and light characteristic of the alpine region could produce a type varying about a new average, which lies near one of the extremes of the fluctuating variations of the parent species.

If this new average should be established within the limits of the transgressive variations of the two species, one of which existed in northern Europe and the other in central Europe, we should have the production of similar types, the alpine and arctic type, in widely separated regions and from different parent species. The characters of the new type are not "fixed" in the sense of being due to inheritance, but only in the sense that they are a response to a particular combination of external factors, and this combination is constant in the given regions. Such a view of the origin of alpine types is not merely of theoretical interest, since the application of the physiological method gives the means of reaching more or less definite conclusions.

De Vries and others have pointed out that the species of the manuals and the systematic botanists are in large part composite or collective species and not simple or elementary species. In his view the latter differ from their parent species by *new* characters not by modifications of old ones. The new characters are inheritable as soon as they appear, and are not regulated by the external conditions in which the adult plant lives.

If Mac Dougal's work stands the test of repetition physiological experiment may open up a new field in investigating the *origin* of species. One method of applying physiological experiment to determining the *limits* of species has just been discussed. But other applications of this method are possible. It is well known that cross fertilization generally takes place only between closely related species of plants, rarely between genera. When attempts are made to cross species remotely related, either the pollen does not grow upon the stigma of the strange specie, or fertilization of the egg does not take place, or if seeds develop the resulting hybrid is sterile, not being able to produce seeds for its propagation. What lies at the basis of these physiological differences is still obscure. It is probable that enzymes, toxins, or other chemical substances play a part. But whatever the explanation, the

fact may be used in determining the nearness or remoteness of the relationship between forms. This possibility has been recognized by many investigators and biologists have proposed using the degree of fertility of hybrids as the means of distinguishing genera, species, and varieties. Though this has been found not to be reliable in all cases, de Vries has suggested it as a means of distinguishing his elementary species from varieties. If on crossing two forms the resulting hybrid is constant in regard to a given character, when guarded against further crossing, the two forms were different species. But if, on crossing, the descendants of the resulting hybrid follows Mendel's law of hybrids according to which one-fourth of the offspring of the hybrid in each succeeding generation resembles one parent in respect to a given character, one-fourth resembles the other parent as regards the corresponding character, while half are like the original hybrid, then the parent forms of the hybrid were one and the same species.

Whatever the limitations of this method in its practical application, the significant fact is the extent to which physiological conceptions have invaded a realm that was purely morphology. We may use the experimental method in studying the origin of new species and varieties. We may apply physiological methods in determining the range of the fluctuating variations within the species. We may use physiological affinities as the test of the degree of relationship existing between different forms found in nature.

The foregoing discussion has had special reference to the higher plants. But among the lower forms of plant life physiological methods are far more applicable, indeed necessary, in determining the characteristics of species. In all that group of plants known as bacteria, species can be distinguished only by physiological means. These organisms are so simple in structure, their morphological characters are so few, it is utterly impossible to classify our knowledge of them even from a systematic point of view without using physiological means as a basis of species distinctions. The most important relations which the bacteria bear to the organic world in general, and to the human race in particular are physiological in their nature. Some of them have the power of invading the animal body and producing there substances which we call toxins, and which may be so exceedingly poisonous that the result may be fatal in an extraordinarily short time. Fortunately the animal body has the power to vary its ordinary physiological processes in such a way as to produce antitoxins which neutralize the action of the toxins. A given organism may vary in its virulence at different times. An epidemic due to an organism in the so-called attenuated state, produces a mild form of the disease. A given animal or plant may be especially resistant to the toxin of one species of bacteria, as the horse is to diphtheria toxin, or it may be very susceptible to a given toxin, as the human body is to the toxin of tetanus or lock-jaw. Also the same organism shows different powers of resistance, or immunity at different periods. It is well known that any conditions of life that produce a low state of vitality in a given individual, make that individual far more susceptible to disease, that is, to the toxins of other organisms. Not only are plants and animals susceptible to the toxins produced by other plants and animals, but each organism produces substances which are toxic to itself. This is true not only for the lower organisms, but at the present time a discussion is being carried on as to whether the necessity of the so-called rotation of crops of higher plants is more dependent upon the partial exhaustion of the soil in elements necessary for a given crop, or upon the gradual accumulation in the soil of substances detrimental to the kind of plant that produced them. The question of the physiological varia-

tions of organism, and the physiological relations of one kind of organism to another, forms a series of the most fascinating as well as the most difficult of biological problems. The small size of the bacteria and the rapidity with which they multiply make them very favorable subjects for experiment along the line of the fundamental biological processes. An organism that requires several hundred years to complete its life cycle is obviously not a favorable subject for an experiment that requires the study of several generations. But if, as in the case of some of the bacteria, a new generation may be produced every fifteen minutes, it is possible to obtain within a few hours hundreds of generations and millions of individuals.

There is another group of organisms about which I wish to speak, not so simple as the bacteria in structure, but far inferior in that respect to the highest plants. I refer to the filamentous fungi, and I wish to call your attention to some facts that again have to do with the question: What is a species? As in the case of higher plants, the first attempts to classify these organisms were upon a purely morphological or structural basis. But a deeper knowledge of their life histories and physiological variations make it more and more apparent that here, as among the bacteria, it is necessary to use physiological means of distinguishing, shall we say species? For the present we can avoid making the decision, and say forms or races, yet at the same time we can hold our minds open to evidence as to whether these forms or races are not after all incipient species. Two groups of these fungi especially force themselves upon our attention from the point of view we are considering. One of the groups has been called the Uredineae or rust fungi, and the ordinary rust of cultivated cereals is a typical example. The other group is known commonly as the mildews, or more technically the family Erisyphaceae. The rose mildew and the grape mildew are common examples. In both of these groups it has been found necessary to distinguish what have been called biologic forms or races, distinguished from each other only by the fact that they differ in capacity to infect different species or genera of the host plant. Working with the wheat rust, which was formerly supposed to be the same on many of the cultivated cereals and wild grasses, Erikson has found that there are numerous races adapted more or less closely to the species of single genera, and they are able to infect species of other genera either with difficulty or not at all. Their forms cannot be distinguished morphologically, and yet the infection experiment shows that physiologically they are decidedly different from each other. In trying to conceive the origin of these forms, there seems to be three possibilities. First, These biologic forms may have had an origin from different species growing on a narrowly limited group of host plants. There seems to be little evidence for this view. Second, They may have been derived from one species, by sudden physiological changes in the fungus alone, without any influence of the host. This would be similar to the origin of elementary species by mutation, as found by de Vries among the evening primroses. There seems to be no direct evidence for this view. Third, a group of biological forms which cannot be distinguished morphologically may have originated from one species which at first grew on a wide range of host plants, but when a strain or race is propagated continuously on the same species of host, there is a special adaptation of the fungus to that species of host, and it becomes able to infect that one more readily, and others less readily, and at last not at all. For this view there is some direct evidence. A form of rust which was capable of growing on four genera of host plants, was propagated for ten years continuously on only one of the four. At the end of the ten year period it

could infect that one genus strongly and the other three weakly or with uncertainty. If this experiment indicates the way in which the biological forms have come into existence, they have originated, not by mutation, but by adaptation. The difference they exhibit have come about by the gradual accumulation of imperceptible modifications.

Among the mildews there has been found an adaptation of forms even closer than among the rusts. Experiments of Salmon on the mildews of grasses disclosed the fact that adaptation is not only to one or few genera, but in many cases actually to one or a few species within the genus. The mildews exhibit the phenomena of adaptation carried much farther than it is carried among the rusts.

The question remains, can these biologic forms or adaptive races ever rise to the dignity of true species. Again the direct evidence is lacking. But if these fungi are as variable in their morphological character as Klebs found even the flowering plants to be under different physiological conditions, we might expect the same causes which bring about the physiological adaptation to be able to produce morphological differences as well. But even if no morphological differences appear, are we not justified in making physiological characters the basis of species among the fungi as is already done among the bacteria? The speaker is inclined to answer this question in the affirmative. It seems certain, that for practical purposes at least, it is becoming absolutely necessary in other groups of fungi as well as in the rusts and mildews, to make distinctions on physiological grounds, not to the exclusion of morphology, but in addition to it. Whether you call the groups of individuals so distinguished species or not, matters very little. The important thing is that the distinction must be made.

It is impossible to apply de Vries' test for species and varieties among the fungi. For most of them there can be no such thing as cross-fertilization. For many there is no fertilization at all, and even where present it is generally strictly self-fertilization. Naegeli long ago pointed out that where plants are propagated only vegetatively or by self-fertilization, and it may be added parthenogenetically, individual peculiarities were perpetuated in the descendants, while with open or cross-fertilization the peculiarities of one individual may be modified in the next generation by mingling with another line of inheritance representing peculiarities of another individual opposed to those of the first. Open or cross-fertilization therefore tends to keep the species homogeneous by neutralizing extreme individual variations. While in those plants which are propagated by parthenogenesis, that is where the eggs develop without fertilization, or by self-fertilization, or by nonsexual spores, or by vegetative means, the species tend to become heterogeneous. They are made up of many lines of descent which are never mingled, individual peculiarities tend to become extreme, and species limits are particularly difficult to determine. Among flowering plants the hawkweeds furnish an example of the results of reproduction by parthenogenesis. In this genus, Hieracium, it is said that of two noted men who had made special study of the species of the genus, neither could identify the species by the other's descriptions. The same result is apparent among the fungi, in the development of the biologic forms or adaptive races. Individual adaptation to a given host is not neutralized by fertilization from a plant with a different adaptation, but is continually accentuated. The practical importance of many of these adapted forms compels us to recognize them as distinct entities, and to give them names. For practical purposes then they are species, even though they can be distinguished only physiologically.

This capacity for physiological variation or adaptation on the part of fungi is significant in another direction. It is certain that among the fungi as well as among the bacteria, forms that for the most part live only on dead organic matter, that is as saprophytes, may under certain special conditions become adapted to a parasitic life. They thus become the producers of new diseases. Though for the most part supposed new diseases are only a wider distribution of old diseases, it is entirely possible for new diseases actually to originate by physiological adaptation. This has been proved in the production of plant disease experimentally.

But if this kind of variation has its somber side, there is also an obverse side. Physiological variation enables us in many cases to select and propagate cultivated plants that are particularly resistant, and sometimes completely immune, to a given disease. The same phenomenon may be observed here as in the human family. In any given epidemic there are always certain individuals who never contract the disease. They have a certain natural immunity to that particular disease, and this immunity is due to some physiological peculiarity. So in a field of rusted or mildewed wheat some individual plants show themselves more resistant than their fellows to the species of rust fungus found upon that species of host. By selecting and propagating these immune individuals we may develop an immune race or strain. The problem is not always so simple as here stated. It may happen that a race immune to one disease may be very susceptible to another, or immunity may be accompanied by other qualities altogether undesirable. One might be led to suppose on reading certain popular articles intended to show how new forms of plants are produced that it is only necessary to imagine an ideal plant and then set to work to create it. Nothing is farther from the truth than this. Nature does sometimes produce something new, as a stoneless plum, or a nectarine on a peach tree. But man can only take the materials furnished by nature, combine them in new ways, or modify them within limits which are usually soon reached. He cannot create a wheat plant immune to rust, nor a watermelon resistant to the wilt fungus. But if nature furnishes a few individuals with the desired qualities, man can propagate the individuals possessing these qualities, and by rigid selection maintain the qualities to a high degree. If it is possible to cross the plants with other species or with varieties of the same species, he may be able to combine in the same individual a number of desirable qualities. Having obtained these qualities in one individual, he can best conserve them by vegetative propagation, such as by grafts, cuttings, bulbs, or tubers, according to the habit of the plant propagated. He may care nothing whatever about the limits of species or varieties except in so far as their physiological relations help or hinder his combinations. Following Mac Dougal's method it may be possible to produce in plants some new characters. But even if it be possible to produce in this way really new species, it is hardly within the range of possibility that we could choose beforehand the kind of a species we would produce. It would be a case of "cut and try." If the result be a form with desirable qualities, preserve it, but if it be worthless let it die. Nature has repeated this experiment ten thousand times. If we would imitate her we must search out her secrets in the physiological realm. She conceals them well, but is not unwilling to reveal them to him who questions her with a hearing ear, a seeing eye, and a thinking brain, tools which she herself has given him.

University of Michigan.

EARTHQUAKES VIEWED IN A NEW LIGHT.*

WILLIAM HERBERT HOBBS.

Mr. President, Members of the Michigan Academy of Science, Ladies and Gentlemen:

It is safe to say that the last twelve years have registered an advance of our knowledge of earthquakes not paralleled by that of any earlier period of the same length, if it is, indeed, by that of all earlier time. The collection of data essential to so grand an achievement has necessarily extended over a somewhat longer period and has been made in earthquake countries, more especially, however, in Italy, Austria and Japan. Nowhere else has earthquake study attained to such well-planned refinement as in Japan. It may seem, therefore, somewhat remarkable that the two men to whom more than to any others we owe the recent advance of seismology, are residents of countries within which earthquakes belong to the rare and curious, rather than to the most common of natural phenomena. The Count de Montessus de Ballore, who has given us the new science of seismic geography and who has discovered a law to connect earthquakes with the relief of the country, is a major of artillery in the French Army. Professor John Milne, to whom more than to any one else we owe the so-called "new seismology," or the study of "unfelt earthquakes," now resides near the little station of Shide, upon the Isle of Wight. Both these distinguished seismologists have made earthquakes the study of a lifetime, and each was formerly a resident in provinces which, to use the picturesque continental expression, have been tormented by earthquakes.

The grander results of recent earthquake study may be summed up in a few words. Perhaps most important of all, the long supposed genetic connection of earthquakes and volcanoes has been shown to be without a basis of fact. Speaking broadly, the earth provinces where volcanoes are found are generally those of important earthquakes, and light earth shocks are an accompaniment of all grander volcanic eruptions, as they are likewise of explosions in mines or of the passage of a railway train; but as regards the great earthquakes, it is found that they show no quick sympathetic relation to volcanic outbursts within the same province. Further, it has been found by the Count de Montessus as the result of the analysis of no less than 170,000 separate earthquake shocks, that a law connects the seismicity (which we may translate the "earthquakeness") of a province with its topographic relief. Other things being equal, the steeper the slope, the greater the danger from earthquake shocks.

The most sensational of the newer revelations in siesmology has resulted from the "distant" study of earthquakes at properly equipped earthquake stations. In the year 1883 Professor Milne wrote, "it is not unlikely that every large earthquake might, with proper appliances be recorded at any point on the land surface of the globe." The fulfillment of this cautious

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* Address delivered by invitation at the annual meeting of the Michigan Academy of Science.

prophecy was assured when, six years later, von Rebeur-Paschwitz found in the records of a horizontal pendulum certain abnormal movements which he traced to earthquakes at great distances from the observing station. The great Indian earthquake of 1897 was the first to be studied at distant stations, namely, in Italy, Germany and England; but today the globe is dotted with earthquake stations well distributed over its surface. Every heavily shaken district whether accessible upon the land areas or upon the bottom of the sea, has its shocks recorded not at one but at many stations; and from these earthquake watch-towers it may be quite accurately located through a very simple calculation. Thus, for example, an earthquake in New Zealand telegraphs its own report to Professor Milne at his station in the Isle of Wight, though this is almost exactly upon the opposite side of the planet; and it occupies, moreover, but a little more than twenty minutes in transmission. This first report is dispatched through the body of the earth, but other and slower messages are sent along the surface with velocities only one-third as great, and these arrive over the longer route some hours after the first intelligence. Still later come the telegraphic reports of the disaster, though these may be delayed for days as a consequence of ruptured cables.

The distant study of "unfelt" quakes has revealed to us facts of the first order of importance. Of "world-shaking" earthquakes, comparable in intensity to the one which visited California last April, we know that no less than 70 occur each year, 90% of which are fortunately upon the floor of the ocean. Each of these disturbances throws into agitation the entire earth's crust, the surface movement being transmitted as a slow swell which even at the most distant points has sufficient intensity to raise the surface of the ground a number of inches, and would be perceived were it not so slow. The waves which first arrive at the earthquake station come by the direct route through the earth's mass, and these have told us that the substance of the earth's core is about $1\frac{1}{2}$ times as elastic as the best tool steel. To have discovered a direct method of studying, upon the one hand, the interior of our planet, and upon the other, geological changes which take place at the bottom of the sea, will hardly be considered small contributions to the sum of human knowledge.

Fascinating as is this distant study of unfelt quakes, it is to the no less interesting and more purely geological phases of our subject to which I wish to draw your attention this evening. The supposed dependence of earthquakes upon volcanic sources of energy in its more concrete form has assumed that gases are imprisoned at some place within the crust—a locus or center—and in their struggles to free themselves they send out sharp seismic waves. This focus or centrum idea has come down to us from the Greek philosophy, and was common enough in the Middle Ages. When in Henry IV Glendower boasts that the heavens were on fire and the earth was shaken at his birth, Hotspur is made to say:

"O, then the earth shook to see the heavens on fire,
And not in fear of your nativity.
Diseaséd nature oftentimes breaks forth,
In strange eruptions; oft the teeming earth
Is with a kind of colic, pinch'd and vex'd
By the imprisoning of unruly wind
Within her womb; which for enlargement striving
Shakes the old beldame earth and topples down
Steeples and moss-grown towers."

As a modern scientific theory the earthquake centrum dates from the elaborate description by Mallet of the great Neapolitan earthquake of 1857. How firmly the idea was then implanted is shown by the fact that Mallet made no attempt to prove the existence of a centrum, but devoted all his energies to fix its location. By methods which are now known to be wholly unreliable he obtained a great number of results ranging with noteworthy uniformity from depths of 10,000 to 45,000 feet, and it is significant of his state of mind in respect to the certainty of a centrum, that he adopted the average depth for its exact position. His assumption was, in short, that within this subterranean "focal cavity" gases were imprisoned and their struggles to liberate themselves sent waves in all directions with equal velocities. These waves would reach the surface of the earth first at a point immediately above the centrum—the epicentrum—and at later instants the disturbed points would be situated upon lines roughly circular in outline and surrounding the epicentrum with successively larger and larger diameters. This conception of the cause of earthquakes rendered it manifestly impossible to establish relations between earthquake shocks and the geological structure of the country, and thus the field of seismology came to be yielded by geologists to a group of applied mathematicians now generally referred to as elasticians. For nearly half a century the centrum theory has now been orthodox doctrine, and an elaborate superstructure of ingenious mathematical deduction has been raised upon it as a foundation.

The revelation that large earthquakes and volcanic eruptions within the same province are not sympathetically related, has removed at one stroke the *raison d'etre* of the centrum idea. It is also a significant fact that the great achievements in seismology during the past twelve years have been reached by studies which have largely ignored the orthodox faith of the science.

The history of science has furnished many examples of theories which have contained a small element only of truth, but yet enough to suggest experimentation and to widen the field of study. Such theories have evolved through enlargement of the true and elimination of the false. The centrum earthquake theory illustrates a false though quite plausible assumption, the effect of which has been like a bandage before the eyes shutting out the light and involving in deep mystery even the simplest of natural phenomena. It will be my endeavor in the brief time that I may claim your attention to present earthquakes in a new light, or, in other words, as geological phenomena to be studied in relation to the changes in the earth's surface by which they are accompanied, and upon which they appear to depend.

In order to bring before our minds the more important of earthquake phenomena we may profitably consider for a few moments the great Indian earthquake of 1897, which deserves to rank with the greatest in history. No earthquake has been more fully or more ably studied, and the results, well illustrated, completely fill a bulky volume of the Memoirs of the Geological Survey of India. Almost the total damage which resulted from this earthquake was the result of the initial shock, and all destruction occurred within the first fifteen seconds of the disturbance. Before two and a half minutes had elapsed all of the heavy shocks had passed, but in this brief interval of time an area of one and three-quarters millions of square miles had been shaken, and one hundred and fifty thousand square miles had been laid in ruins.

A member of the staff of the Geological Survey of India, who was in the town of Shillong at the time of the earthquake, has stated that a rumbling

sound like near thunder preceded the shock by a second or two of time, and increased in intensity so that the falling of heavy masonry buildings a few rods away was not audible. Unable to keep his feet he sat down upon the ground, and not only felt but distinctly saw the ground thrown into violent waves, "as though composed of soft jelly." These waves appeared to advance along the ground, and induced in him a feeling of nausea akin to seasickness. When the shocks had passed all masonry structures had been leveled to the ground, and over each hung a cloud of pink plaster particles and dust. Above the town in the park a horseman noticed that a peculiar rustling of the leaves upon the trees preceded the first sounds by a brief interval of time as though resulting from an earlier tremor.

By many the shocks were described as in places gyratory or twisting in their nature, and monuments which were built up of sections revealed an increasing amount of rotation for those higher blocks in the structure which had not been completely detached.

Over large areas the surface of the ground was rent by numerous fissures, large or small, and some of these had great extent. It was noticed that these fissures followed in their direction the lines of the ranges of hills. Sometimes they gave the impression of having opened and later closed under great pressure, as the ground was raised in a furrow. If sandy, the ground apappeared as though a steam plow had passed over it, tearing up the surface and throwing heavy clods in every direction. Posts were sunk deeper into the ground and were surrounded by a cup-shaped depression. In many instances monuments and even houses were similarly projected into the sandy ground so that only the tops and roofs remained visible.

In addition to the numerous cracks, crater-like pits appeared in the ground. These were usually about six feet across, though sometimes more, and through them jets of sand and water were thrown to a height of seven or eight feet, and probably much higher. Mixed with the sand were fragments of peat, coal, resin, half-petrified pieces of timber, and a black earth at the time unknown in the district. The same materials also welled up through some of the fissures. The large amount of sand thus brought to the surface was spread around the orifices in flat domes, and where these were most numerous the entire face of the country was flooded, and after an interval blanketed with a layer of quicksand in which cattle floundered and were held fast. The local streams were swollen suddenly and raised from two to ten feet, though they settled back to their former levels shortly after. The Brahmaputra advanced as a wall of water ten feet in height.

In the Garo and Khasi hills the numerous land slips within the weathered sandstone rocks developed wide spread fans of sand at their bases. The rivers of this section are ordinarily a series of deep pools separated by rocky rapids, though in flood-time they changed to raging torrents. Following the rains after the earthquake of 1897, the pools were found to be filled up with sand, the rapids obliterated, and the streams flowed over the sandy floor of a broad and shallow channel. In this hill country were found the most interesting of the geological changes. Although only a single zig-zag journey was made through the country, three large earthquake faults, hundreds of great fissures and no less than thirty lakes were found to have resulted from the earthquake. One of these lakes was more than a mile across.

The largest of the earthquake faults, known as the Chedrang fault, adhered to the course of a meandering but otherwise straight river, and was thus followed for a distance of twelve miles. The vertical displacement or throw

revealed by the walls of this fissure was in one place no less than 33 feet, but it changed most abruptly and frequently. Where the upthrown side of the fault cut the course of the river on the down stream side, the waters were impounded into a lake, but otherwise a waterfall resulted. Sometimes the fault was double, and examination of a ledge of rock 200 feet distant from it showed that adjustments amounting to several inches had occurred on many of the vertical fissures by which it was intersected. Throughout movements appeared to have been upon essentially vertical planes of fissure.

At places along the course of the Chedrang fault the ground was tilted for a considerable distance in the direction of the course of the fault, and in some cases small lakes resulted from this cause. A roughly cubical block of granite 40 feet long, 30 feet wide, and 30 feet high, which had lain across the course of the fault, had by the movement upon it been completely overturned. Elsewhere in the vicinity large boulders were seen to have been lifted out of their hollows, projected for a considerable distance, and left in some instances overturned with the dirt still adhering to them.

In the report upon the district the name fracture is given to the numerous visible fissure planes on which no observable vertical displacement, or at most a very small one, could be made out. Of these there were hundreds observed, the largest of which became known as the Bordwar fracture. This fissure was followed for about 7 miles in a straight line as a crack in the hard gneiss rock, and showed in places a few inches of displacement. Its course could, however, be easily followed by overturned trees, broken bamboos, land slips, or as a small ditch in the surface of the ground.

Important changes of level of great blocks of country were clearly shown by the alterations in the aspect of the landscape. Ranges of hills which before had not been visible from certain points, now for the first time came into view, while others had disappeared. In at least one instance some measurement of these changes was carried out. So soon as it was noted that the changes had taken place, lines of sight to definite points in the landscape were determined through the nailing of boards to stout posts. Later observations along the same lines gave some measure of the subsequent changes in level. Shortly before the earthquake, a primary triangulation of the district had been carried out, and a resurvey made subsequent to the disturbance revealed changes in elevation of stations by as much as twelve feet, and of location by about the same figure.

Though the most destructive shocks arrived during the first few seconds of the disturbance, those which immediately followed were heavy enough to have caused great damage had not all structures been already leveled. Shocks of lesser intensity were felt for more than a week, but these gradually faded away. At a point located near the great Chedrang fault, it was noticed that the surface of a glass of water did not come to a rest for more than a week after the disturbance. Observations proved, however, that after shocks were less numerous in the vicinity of the faults than elsewhere within the affected region. When the shocks had ceased to be felt as waves they continued to be perceived as low rumbling sounds. In this period observations extending over twenty-three hours furnished a record of 48 separate disturbances, only 7 of which were accompanied by sensible shocks.

The description of this earthquake has placed before us the more important characteristics of large earthquakes. A great earthquake affecting especially the floor of the ocean would have differed by producing a great wave, such as has generally been erroneously designated a tidal wave.

Such was the great Lisbon earthquake of 1755, the wave from which traveled throughout the surface of the globe, or the Japanese earthquake of 1896. Earthquakes which occur upon a coast line also furnish us with a better indication of the changes in level of the surface of the ground, since the sea level is here a datum plane for measurement. Not only do earthquakes bring new lakes into existence, as was the case in the lower Mississippi in 1811 and in India in 1897, but lakes and swamps already in existence are frequently drained. Such changes were particularly well illustrated by the great earthquake in the lower Mississippi valley in 1811. The bottoms of the drained lakes thus exposed to view, showed the ground divided into strips with funnel shaped holes along them down which the water had been sucked in vortices. Sometimes the water which wells up to the surface gushes not only from crater-like pits but throughout the length and breadth of long fissures, only to be the next instant sucked down again. In other cases the water of swamps is first drawn away, to be as suddenly returned through the newly formed fissures.

Within an earthquake district wells and springs are nearly always affected by the shocks, and show either an increase or a decrease of flow. Wells which pierce the water table far below the surface often fill suddenly and flow over at the surface immediately after the first shock, after which they often fill up with sand, and perhaps then suddenly cease to flow.

The geysers of Iceland are many of them known to have been born during earthquakes within the province. The famous Strokkur, which had come into existence during the earthquake of 1789, ceased erupting during the earthquake of 1896, and has since appeared to be quite extinct. The whole subject of the derangement of the surface and underground flow of water during and after earthquake shocks, has not been susceptible of explanation upon the centrum theory, and on this account has been almost wholly neglected; yet there is no more constant feature or fascinating subject for study in the whole domain of seismology.

Earthquake faults such as were observed to have formed during the Indian earthquake of 1897, are likewise a no less constant phenomenon in connection with all great earthquakes. Faults of large dimensions have, however, in each case been relatively few in number. During the Mino-Owari earthquake in Japan in 1891, there was formed but one large fault, though this extended for nearly one hundred miles across the country, and in the Neo valley exposed a nearly vertical displacement wall in places as much as 18 feet in height. The ground upon one side of the fault was seen to have been raised bodily so as to form a high terrace where the land had before been level. This section of land was, however, in places, not only moved upward, but also shifted laterally in the direction of the fracture, so that highways severed by it no longer matched upon its two sides. Trees upon opposite sides of the fault which before had been in an east and west line were afterward aligned upon the meridian. At other points along the fault where the displacement had been less and the cover of soil more, its course was marked out not by a nearly vertical wall, but by a so-called "plowshare" appearance due to adjustments within the loose overlying material. The numerous rounded edges of this character which are nearly always formed in connection with Japanese earthquakes, are responsible for the belief prevalent in the country, that a giant cat-fish moves beneath the surface during an earthquake and by his movements gives rise to the shocks.

Only one large surface fault appears to have been formed at the time of the recent California earthquake, though this has been followed in a some-

what broken line for between 200 and 300 miles. Where this fault intersected roadways, fences and other artificial features, it was patent that the land upon the southwest side had been bodily shifted northward a maximum distance of about 21 feet. During the Japanese earthquake of 1896, as well as during the Sonora earthquake of 1887, two great faults opened upon opposite sides of mountain ranges and the entire included range was bodily uplifted between these fissures by several feet.

Smaller faults and fissures born during an earthquake are numbered by the hundreds or even thousands. When these appear in parallel groups the ground is sometimes actually sliced by them, as was the case in the recent Alaskan earthquake of 1899. Again, individual fissures may zig-zag across the country with gaping sides, or be detected only through the derangement of the surface drainage within the district.

With this introduction to my subject, I shall take the liberty of referring to certain observations which I made in Calabria about a year and a half ago, and directly after the heaviest earthquake of that region in more than a century. I was so fortunate as to reach the affected district while the work of succor was still only in part accomplished, and when the destruction wrought could be examined to the best advantage. In Monteleone, though the greater part of the city had escaped serious damage, one could look down the entire length of the Strada di Forgiari along a straight and narrow lane of destruction as clearly marked out as the track of a tornado. Going into the country upon either hand this line was found to be extended by ruined villages, yet nowhere was there a fissure in the ground. General Ferrario, who commanded the division of regular troops engaged in the work of succor, had established his headquarters at Monteleone, though his command had been largely dispersed through the province in order best to render assistance to the people. All reports from subordinate commands reached headquarters at Monteleone, and with commendable scientific spirit they had been entered upon a great maneuver map in such a way that communes which had suffered most appeared as red spots upon the map. As soon as this map was exhibited, I remarked that the red spots fell within straight lines which were generally parallel either to the coast line or to the margins of the mountain masses, only to find that this observation had already impressed itself upon the staff.

Such a localization of special damage from earthquakes along a series of lines which sustained relationships to the relief of the land surface, obviously called for explanation; and as the borders of the mountain masses had here in most cases been recognized by geologists as fracture lines, it was at once suspected that the observed relationship was accounted for through an adjustment at the time of the earthquake between different sections of the earth's crust outlined by the fractures. It had been noticed, after the earthquake in Japan in 1896, that when the surface faults appeared to die out, their continuation could be followed over the loose soil which covered the rock in the lines of ruined villages. Should it be true that in Calabria the movements had taken place upon hidden planes within the crust, it seemed likely that these planes would have been the seat of movement not once only but many times when earthquake shocks had been felt within the district.

No country save perhaps Japan can rival Calabria in the long and tragic record of its earthquakes. For purposes of study an additional advantage favors Calabria, since an Italian seismologist of reputation has recently compiled and carefully edited the scattered records in a work of nearly one thousand pages. My field work completed, I repaired to Rome and devoted

the winter months of 1905-06 to a survey of Calabrian earthquake records for the last three centuries, and for purposes of comparison large scale maps were prepared to show the distribution of damage from each earthquake individually. The result has been a confirmation of the working hypothesis, for the lines of damage indicated by one earthquake have been found to be those of the others as well, save only that the heavier disturbances have corresponded to movement also on certain additional fracture lines. It was with considerable satisfaction that I found in the records of the great earthquake of 1783 a statement that the initial shock had leveled the buildings along the Strada di Forgiari in Monteleone but had not affected the other buildings of the city. Unlike strokes of lightning, therefore, earthquakes appear to search out the same places for their repeated attacks. From these Calabrian studies we may conclude that at the time of earthquake shocks opportunities for learning important facts are afforded which at other times are denied to us. The earth's surface is at the time of an earthquake, so to speak, sensitized to reveal its hidden architecture, much as are our bodies under the influence of the x-rays or the fluorescent screen.

An additional fact of importance foreshadowed upon the staff map of Gen. Ferrario was that the points of intersection of the lines of special damage had received much the heaviest shocks. Without appreciating its significance this fact has been unconsciously recognized in Italy by those officers whose duty it has been to receive and classify the reports of damage from earthquakes. When an earthquake has been announced in a definite province of the Italian peninsula, men familiar with the earthquake history of the district can tell in advance what communes will probably report damage and what others will have been immune. It is, in fact, wholly possible upon the basis of reports now upon record to derive numerical figures which, in a relative scale, set forth the danger from earthquake shocks of each commune in Italy.

The lines of special damage from earthquakes—the so-called seismotectonic lines—are found to be in most cases the generally rectilinear features upon the surface, as, for example the borders of plateaus, the bluffs along the coast, the boundaries of geological formations, the sharp lines of drainage, or, perhaps, the line joining waterfalls in neighboring streams; but in any event lines relatively straight and technically described as lineaments.

When the Calabrian studies just referred to had been completed there appeared the great work of the Count de Montessus upon Seismic Geography. By a method of compiling and standardizing, so to speak, all the earthquake records within each earthquake province of the globe, de Montessus has prepared a series of maps which, speaking broadly, show the distribution of danger from earthquakes within each of these provinces. The results are the more reliable in those provinces where careful records have been longest preserved, but collectively they possess a value which, in view of the painstaking statistical researches upon which they are based, it would be difficult to overestimate. Examining now these maps with reference to the lineaments of the surface, it was a special satisfaction to find that with hardly an exception they show the special danger spots to lie at intersections of the prominent features within each district. Two maps may be chosen by way of illustration—the northern section of the British Islands and the Greater Antilles. In both these cases the earthquake danger spots are ranged upon the lineaments, with the places of special seismic prominence located at their intersections.

We may now come nearer home and survey for a moment an earthquake

map of the Atlantic coast states. The more prominent lineaments are here brought out in dotted lines, and it will be noted that upon them are ranged the spots which indicate earthquake damage in the past and presumable earthquake danger in the future, with the largest of the spots at lineament intersection. Note, for example, the "northern fall line," on which are ranged Washington, Baltimore, Wilmington, Philadelphia, Trenton, New York, New Haven, East Haddam (Conn.), and Boston. This line marks a well known fracture in the earth's crust at which formations of widely different geological age have been joined and where slight falls in rivers have determined the head of navigation, and with it the location of the port cities.

The largest spot upon the map is East Haddam, Connecticut, where the fall line intersects the straight gorge of the lower Connecticut. From the earliest colonial days this town has been shaken by light earthquakes which have generally not affected the surrounding country and which have been accompanied by subterranean rumblings. Upon its site stood the ancient Indian Village of Morchemoodus, or the "Place of Noises." Almost as noteworthy for its earthquakes as the northern fall line is the central New England coast line, the Boston-Augusta line, upon which are the prominent earthquake towns of Newburyport and Boston, as well as Pt. Judith, Greenwich, Portsmouth and Portland. Upon the southern fall line are similarly aligned the earthquake towns of Macon, Clinton, Milledgeville, Saundersville, Augusta, Aiken and Columbia. Like the northern fall line this lineament is a boundary between geological formations and is marked by rapids in the rivers which fix the head of navigation.

It appears from this map of the Atlantic coast region that the lines of special danger from earthquakes may not be lines of relief in the surface; and hence in a more elaborate analysis of earthquake shocks the law of the steepest slope is not verified. Yet in many, perhaps in most cases, each seismotectonic line is either in some part of its course or in its extension, a line of considerable slope upon the earth's surface. Thus, for example, the northern fall line is to the southwest of Washington in coincidence with the steep southeastern base of the Appalachian mountain system, the steepest slope within the province studied. The central New England coast line, which at first sight might appear to constitute an exception to the rule, if extended southwestward across the continental shelf, is found to correspond in position to that remarkable escarpment which is the border of the continental shelf and on which, for a distance of more than 500 miles the ocean suddenly deepens from less than 1000 to more than 9000 feet. Yet, whether a line of relief or not, each seismotectonic line is throughout distinctly marked in some way, whether as a geological boundary, a straight line of drainage, a fall line, or otherwise.

De Montessus's law that earthquake shocks are heaviest upon the steepest slopes must therefore be revised, and may be expressed as follows: *Earthquakes are localized upon earth lineaments—faults—and especially at their intersections.*

Thus we have learned that earthquakes exercise a selective property by searching out upon the earth's surface the lines of fracture within the district, and, it would appear, also, that the heaviest shocks are transmitted in the directions of these fractures. Thus the earthquake of October 20, 1870, appears to have been caused by vibrations which were sent out from and transmitted along the principal lineaments of the New England province. The earthquakes of May 18, 1729, Aug. 10, 1884, and Aug. 31, 1886, have all been especially marked in the chain of great cities upon the northern fall line.

No one of these earthquakes was of catastrophic violence, but we should not on this account delude ourselves by any false hopes that this condition will continue. The so-called "Charleston" earthquake came as a complete surprise, perhaps even to many geologists, but data were in existence upon the basis of which it might have been predicted, though without even a guess as to the time of its arrival. The devastating earthquake which will sometime visit the cities upon the fall line, may not befall in our generation or that of our children or grandchildren, but come it will eventually. When the blow has fallen the cities will be safer because they will know their danger and may, *perhaps*, rebuild with some reference to it. Despite their disastrous consequences earthquakes have served a useful purpose by revealing the lines of special movement where they pass beneath the cities, and as soon as possible after the shocks have passed, a detailed map should be prepared setting forth the distribution of their intensity within each city upon the basis of the damage sustained by its artificial structures. Over the positions of greatest damage public parks, or wide streets should be laid out in the rebuilding of the city, and on no account should structures be again reared above them. To proceed in any other manner is to court destruction.

To one who has followed me in this address, I think it is not necessary to say that, in my view, earthquakes result from mutual adjustments of the blocks which compose the earth's crust and are outlined by a system of fractures. Such fractures, large and small, we have seen are actually in view at the surface after any great earthquake and may be counted by the hundreds, or even thousands. A still larger number, upon which the amplitude of the movement has presumably been less, do not appear at the surface as fractures, though their course is marked out by the lines of special destruction.

It is not necessary to assume that these fractures have originated through the action of those forces which engendered the earthquake; indeed, it is far more likely that most of them existed before, and that the earthquake is the consequence of displacements which have occurred upon them. We have only to look about us in those places where ledges of rock are exposed at the surface to note that when undisturbed from their original position these rocks are everywhere intersected by a network of fissures generlly perpendicular to the earth's surface and arranged in a number of intersecting but parallel series. By these fissures the rocky crust is divided into an immense number of vertical prismatic blocks, which grouped together, make up masses of any size or outline whatever, though always bounded by a vertical wall and capable of being moved *en bloc* upward or downward, laterally past each other, or, even when crushed to some extent, tilted from their position of horizontality. Such movements are the ones actually indicated upon the earthquake faults which are open to our inspection.

I shall not consider myself called upon to give here the reasons which have led geologists in recent years to regard the outermost portion of the earth's crust in which are the fractures above described, as resting, and potentially floated upon a lower rock zone within which a flow of material is the only way in which adjustments may occur. It is enough to say that the view is based upon a consideration of gravitation and the strength of rock material, and confirmation for it is found in the observed behavior of the earth's surface.

It is a fact well known that while some seacoasts, like those of Maine and Norway, have been sinking, others, like that of Florida, have been rising. Upon the continents mountain ranges continue to push up their heads, while the tireless forces of erosion and transportation are as steadily planing

off the elevated areas and depositing their waste upon the seashore in the neighborhood of the land. Such changes inevitably involve a new distribution of the load pressing upon the rocks within the zone of flow, and no argument is needed to show that somewhere beneath the surface a new distribution of material by lateral movements must take place in order, in part at least, to bring about adjustment to the new and ever changing conditions. At any moment places can be found where a strong tendency exists for the withdrawal of some of the material and the supply of a corresponding need elsewhere. A tendency towards withdrawal of material is at the surface above a tendency towards subsidence or settlement; whereas a tendency toward elevation must exist over those districts toward which the material tends to be transferred.

So long as the transfer is delayed, the downward acting forces within the region about to be depressed are met and balanced by equal upward forces due to the rigidity of the rock prisms in the zone of fracture under the strong compression which results from earth contraction. Within the areas about to be elevated, the upward tending forces are similarly met, and the blocks are held rigidly as though between the jaws of a vice. We may illustrate these conditions by a very simple experiment. Within a long narrow tank, of which one side is formed of strong plate glass, is fitted loosely near one of the ends a wall which is hinged upon the bottom. An iron rod of length sufficient to project beyond the wall when fastened in a horizontal position to the opposite end of the tank, is supplied with screw-thread and nut so as to be used as a vice in compressing any bodies within the tank and large enough to occupy most of its area. The tank is partially filled with water, upon which are supported rectangular prismatic wooden blocks which loosely fill the space. Through varying the height of the blocks they are made to float and project by different amounts above the water surface. When the vice has been tightened they may, however, be made to retain other than their natural positions of flotation.

If, now, a board of such size as to fit loosely over the blocks in the tank be allowed to rest its weight lightly upon them, all may be brought to the same surface level, and if the vice be properly adjusted, may be retained in that position when the board is removed. (See Fig. 1.) Tightly compressed in the vice, the bridge of blocks is held in place against forces tending to elevate it throughout those areas where blocks have greatest depth, and to depress it where the block depth is least. If the compression upon the blocks be now gradually removed, a point will at last be reached when the rigidity of the bridge of blocks regarded as a beam is insufficient to hold it in its present attitude, and adjustment will take place. (See Fig. 2.) This adjustment occurs by certain blocks being forced upward and others downward, and when a transfer of water goes on from beneath the latter to the former. Such adjustments of level among the blocks in the bridge correspond to adjustments of crust blocks at the time of earthquakes, and to the formation of earthquake faults upon the block margins.

The water which ascends between the blocks, owing to the fact that they are not perfectly fitted to each other, represents in the experiment the underground water which fills the fissures in all rock masses from very moderate depths down to the zone of flow. As we have seen, the underground water flow is thoroughly deranged at the time of earthquakes, so that within one portion of the affected district the springs flow with unusual volume and bring large quantities of sand and mud to the surface, and in other parts of the same district the water of ponds and swamps is as suddenly sucked down

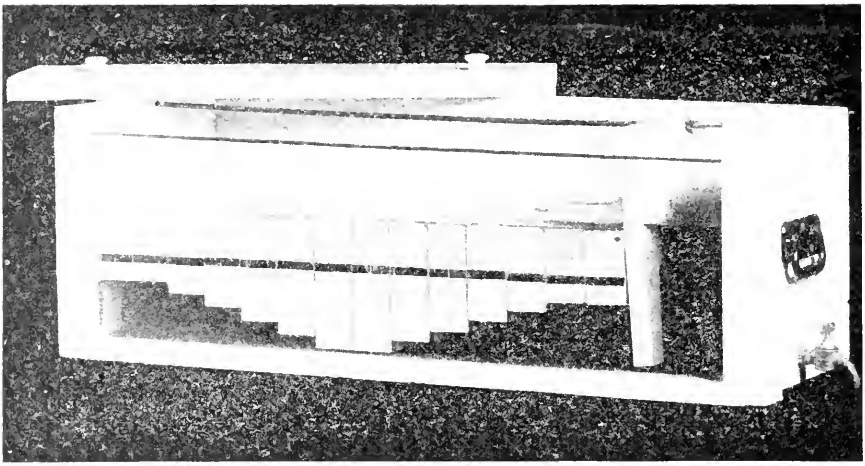

Figure 1.

and disappears. The first mentioned condition is represented in the experiment by those portions of the bridge where blocks are shallowest, and where in consequence they are suddenly dropped when the compression is relieved. If the entire bridge be depressed in such a manner that the water overflows it before the experiment, the opposite condition may be locally illustrated.

Whenever two surfaces slide over each other under pressure they tend to assume a more or less interrupted but progressive movement as a result of friction; and this alternation of quicker and slower motion is transmitted outward in all directions as elastic vibrations or waves, whenever the moving bodies are in contact with an elastic medium. The waves will be of the greater intensity according as the slips are the larger —have greater

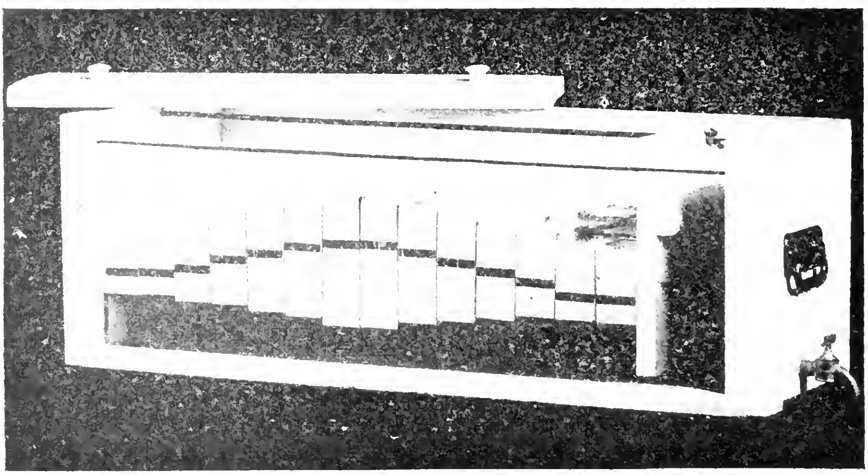

Figure 2.

amplitude—and according as they take place the more rapidly. The surface of a violin bow slips over the strings of a violin, and the elastic air medium transmits the movement as waves of sound, which will be the louder the more rosin is upon the bow—the greater the friction—the farther it is moved over the string and the more rapidly. The motion of adjustment at the margin of blocks produces a fault accompanied by vibrations which are transmitted as earthquake waves by the elastic rock medium. These waves will be of at least two types, one yielding successive shocks which cause damage, the other relatively quick and feeble and perceived as sounds only. Experience has taught that the slips upon earthquake faults are accomplished within a few seconds at most, and often within the fraction of a second; and, further, that a definite relation appears to exist between the size of the faults produced and the intensity of the successional earthquake shocks.

Shocks must be transmitted from every fissure upon which a slip has taken place. The distance to which these waves are carried is much less than has generally been supposed for the reason that the cumulative effect of the slipping on many planes often widely separated from each other, has been erroneously traced to a disturbance supposed to emanate from a single focus near the center of the affected district. It appears that the waves travel with the least loss of intensity along the fissure planes themselves, but in directions at right angles to these fissures their intensity is rapidly dissipated, so that at relative short distances they are impotent against well built structures. Thus may be explained the mysterious and repeated immunity of certain villages from earthquake damage even though situated in the heart of an earthquake district; as well as the hitherto equally unaccountable shocks which have been felt in villages located far outside the so-called destructive zone of the great earthquakes. In far too many instances wholly reliable reports of so-called "freak" shocks which have been felt at great distances from an earthquake "centrum" have been wholly disregarded because in conflict with an accepted explanation.

An oft observed result of earthquake disturbance is the rotation upon their bases of the higher blocks in heavy monuments. A recent illustration has been furnished by the twisting of Queen Victoria's statue in the square at Kingston during the recent Jamaican earthquake. It has long been realized that heavy shocks have reached the same point of an earthquake district from different directions. This has often been illustrated by the throwing of objects first in one direction and later in another. The late Professor Sikiya of the University of Tokyo prepared with much care a twisted wire model which recorded in its changing direction the sequence of the shocks and the exact direction of each for the Japanese earthquake of January 15, 1897. Three complicated snarls of wire were necessary to record in this manner the variation in direction of shocks arriving at a single point for an earthquake which lasted about a minute. These models, which have hitherto been given no satisfactory explanation, we may now interpret as due to the shocks which have reached the station from the numerous fissure planes of the district upon which the movement has occurred. Such waves should reach the station at different times, in different surface directions or azimuths, and with different angles of elevation. Should two or more shocks reach the station at the same instant from different directions, the result must be a rotatory movement, such as would explain the long and gradual curves in the wire as well as the twisted monuments.

I am painfully conscious that it has been possible to touch but lightly

upon the interesting problems which earthquakes offer for solution, and my story has already developed a likeness to the oldtime novel with its prolongation of agony into the third volume. I must not forget that even the "three-decker" has an end, and in Kipling's words:

"She dwindles to a speck,
With noise of pleasant music and dancing on her deck."

If the denouement has been harrowing and you have been shocked by disillusionment concerning the security of mother earth; if it is unpleasant to contemplate some of our great cities quite unprepared in the grip of a devastating earthquake, I can at least offer the assurance learned of our mothers in childhood, that the medicine is for our good. I have observed, too, that dangers which impend often seem less terrible when they threaten us not so much as they do our friends—and especially our more distant ones. I can offer no earthquake insurance, and it is much easier as well as much better for one's reputation, to predict where earthquakes *will* strike than where they *will not*; but it may help you to a restful night, if as a parting word I say that the state of Michigan, as regards earthquakes, is apparently much more secure than either the Pacific or the Atlantic slopes, the Lower Valley of the St. Lawrence, or the Lower Mississippi.

University of Michigan.

THE WATER SYSTEMS IN PLANTS.

J. B. DANDENO.

The importance of water in the physiological operations of plant life, in regard to both the vital and the physical sides, can hardly be of much less consequence than that of air. That water is of extremely high importance in plant economy, is fairly well known. Perhaps, in a general way, it is better understood on account of its tangibility, than are the air relations. But there is much that is intricate and difficult about the actual conditions in connection with the water systems. To point out in a general way the fundamental principles involved in the water relations is the object of this paper.

It need not be said that water is an essential substance in the welfare of plants. All organisms require it. The earliest forms of both plants and animals were aquatic, and consequently required it in abundance. In such organisms the water systems were comparatively simple because the organisms in all stages of their lives were actually immersed in it. But as these organisms began to adopt a semi-aquatic habit, or a land habit, their internal and external structures became modified to suit the changing conditions. However, no matter whether the plant lives immersed in water or in air, water is essential to the vital processes. There are some instances relating to plants in desert regions and to such portions of plants as seeds, which might seem to indicate that water was not absolutely essential, though at first sight they might seem to be. In such cases the organism is able to undergo a dormant existence with only a very small quantity of water. This small quantity, however, is quite essential.

The structures which have to do with the intake of water into organisms in general are: The epidermal cell wall, protoplasmic membrane (which lies immediately within the cell wall and ordinarily pressed firmly against it), the protoplasm itself, and tissues of several kinds. Not less important, perhaps, are those parts which are especially adapted to retaining water which has already been absorbed. These parts assume a great variety of forms both as to tissues and to epidermal outgrowths. In connection with these should be mentioned such forces as have directly to do with the transfer of water from place to place in a plant, or from cell to cell. In close connection with these should be included such mechanisms as have to do with the liberation of water to the surrounding medium. To summarize, then, we present those structures which are concerned in absorbing, in transferring, in retaining and in giving off water.

In regard to plants which lie immersed in water or are floating upon it, the water system is comparatively simple, involving chiefly a physical attraction which has been generally termed osmosis. This phenomenon of osmosis is theoretically not difficult to explain, but unfortunately, there are diametrically opposed views with respect to the theories advanced to explain it. It would not be worth while to go farther into an explanation of the process of osmosis, than to state that there are three essential factors concerned with the process: (1) a premiable or semi-premiable membrane which is extensible and elastic, and therefore capable of reducing the size of, or of enlarg-

ing, the pores in the membrane, (2) water and (3) a substance soluble in water. This membrane must be less premiable to the substance in solution than to water; and it is further assumed that the membrane is not premiable to the same extent with all substances in solution. Now, if these three things be arranged properly, osmotic action will be developed and a current of liquid started. Such is only the merest outline of osmotic action. But the forces involved in such action have to do to a large extent both with the absorption into the plant, and with the transportation of substances (in solution) from place to place within the tissues. The force which produces osmotic action is a physical attraction existing mutually between particles of one substance and those of another, the substance being endowed by nature with this power or force. The ordinary cellulose cell wall is of course readily pervious to water and to solutions; and within the tissues small visible openings in the walls cause water interchange, and transfer from cell to cell to be carried on the more readily. The protoplasmic membrane within the cell immediately adjoining the wall, and also that bounding the vacuole are both concerned with the transfer and with the absorption of water and of solutions. Both membranes have to do with regulating the current through the cells. These membranes possess a peculiar regulative power not only with regard to the quality of liquid but also to the quantity. It seems therefore to have some power of selection varying with the individual, or with the species. But this power is very limited in extent. This regulative power is well exemplified in sea-weeds and the like, which, though immersed in water containing a high proportion of common salt, contain actually a very small amount of this substance, and a much larger amount of potassium, though the latter exists only in very small quantities in sea water.

The most important factor having to do with the movement of water in the water system of plants, is, therefore, osmotic action, and in the lower forms of simple structure, it is practically the only factor. Water plants and land plants require, in a measure, separate treatment with respect to the water systems, and, in view of the fact that water plants are comparatively insignificant in economic importance, as compared with land plants, the latter will be dealt with almost entirely here.

When, in the process of evolution, plants took on a land habit, they developed, in consequence, structures which were more or less adapted to the changing conditions, and such structures were acquired only during many ages of time. Soil and air being the medium in which land plants exist, the water required in the life of the plants must be obtained from these two media. But, as air would be likely to contain liquid water only at intervals, and the soil more likely to contain it continuously, the soil became the natural source of supply, and the organs concerned have been developed accordingly.

The underground structures mainly then are concerned with the absorption of liquid material, consequently the current of soil water through the plant will be from the underground parts towards the parts above ground. And if this current is to be sustained there must be a loss of water at some part of the plant. The air favors this loss because of its affinity for water. But it should be pointed out here that this liquid given out into the air is practically pure water, while that taken by the underground parts contain substances in solution in small quantity.

In order that this transfer from the underground parts (chiefly roots) to the parts (chiefly leaves) above ground, may be made economically certain,

rather well-marked tissue systems have been developed in roots, stems and leaves.

With regard to the entry of solutions into the roots, osmotic action is the chief (practically the only) factor; in transfer from cell to cell it is also the only known factor; but this is necessarily a slow process, and one involving many changes—many of them probably unnecessary—in the character of the solution which entered the root. Consequently more direct systems have been developed, and in the highest forms of plants this system consists of a series of tubes end to end, reaching from the rootlets to the smaller branches of the veins of the leaves. These tubes are modified cells with the end walls gone, either wholly or in part. This system of tubes, sometimes called the vascular system, develops in certain well-defined portions of the plant, and in many cases they, with the accompanying cells, form what is called the fibre of the plant. There are two chief types of arrangement of such fibres in stems—(1) that found usually in dicots, (2) that in monocots. But in roots there is a more varied arrangement.

In the dicots, where the plant is an herbaceous one, these fibres form one well-defined ring around the outside of the pith. The inner portion of these fibres has to do with the transfer from root to leaf, and the outer portion from leaf back towards the root, the one conveying unorganized material and the other organized material. There are many variations from these two general plans, but these details can not be dealt with here excepting in the more important phases.

Four different forms of higher plants may be considered as representing in a general way the peculiarities of the water systems of such plants: (1) a sugar maple tree, (2) a coniferous tree, e. g., the white pine, (3) an annual plant of the dicot type, e. g., the sunflower, (4) an annual monocot, e. g., corn.

The sugar maple as representing a type of woody dicot possesses a system which, in a general way, may be outlined as follows: The root hair absorbs, by osmotic attraction, water from the soil, and this water is passed on from cell to cell through the softer tissue of the root until it is pressed out of the cell adjoining the vessels (tubes of considerable length) into the vessels themselves. These vessels are more or less continuous through the smaller rootlets into the larger ones, then into the roots and up into stem and leaf petiole, into the ultimate veins of the leaf where it is removed by osmotic activities into the living active cells of the leaves. Of course it is quite probable that here and there much of the water is removed from the vessels by the tissues alongside, as the water goes on in its course from root to leaf. These tissues are supplied with water from this source. Openings in the walls of the vessels favor this process very materially. This water as it passes from root to leaf is practically soil water, and is therefore devoid of any organic food.

The forces which contribute towards this ascent of water through the vessels are, capillary action, the force of evaporation in the leaves, inhibition of cell wall, root pressure, atmospheric pressure, activities of the living active cells here and there throughout the tissues, air bubbles in the conducting vessels, osmotic activities in living cells. Whether these are sufficient in themselves to cause an ascent of liquid to the tops of the highest trees is a matter not yet definitely settled. In fact the present view is that they are insufficient.

To trace a drop of soil water from root to leaf of the maple would therefore concisely state the situation. This drop with its small amount of inorganic

matter in solution is absorbed into the root hair which is simply an elongated epidermal cell of the root, by the forces involved in the process of osmosis. It is transferred from this cell to neighboring cells by a similar process, the movement being generally from the cell containing the more dilute solution. In all living cells this dilution is constantly changing by the action of the protoplasm, consequently movements of liquids are set up. But the root hairs are constantly absorbing from the soil and losing to the neighboring cells, therefore a movement would be developed from the root hairs towards the center of the root where the conducting tubes are situated. The soil water is then carried from the soil to the vessels in the root by osmosis. It is forced out of the cells adjoining the vessels by turgor pressure which pressure is maintained merely by increase of quantity of material within the cell. The peculiar arrangement between the cell and the vessel assists very materially. The releasing of water from the cell to the vessel is one of the most difficult steps to explain. It is not easy to see how a cell can absorb water on one side and give it out on the other, and this by the same process. A reference to the ordinary osmometer made from pig's bladder, thistle tube and molasses, may illustrate the point. The solution in the tube becomes greater and greater until the tube overflows. It keeps on overflowing at the top and this tube may be compared to the cell adjoining the vessel, the upper end to the side of the cell touching the vessel, and the bladder end to that joining the neighboring cell. This assumes that the side of the cell next the vessel is more pervious to water than the other side, and that the membrane on the side next the other cell is different in some way from that on the side next the vessel. The former assumption is supported by the fact that well developed pits or openings between cell and vessel can readily be seen. The latter is supported by the membrane theory of osmotic activity, which states that the membrane itself, as well as the substance in solution, or the liquid have to do with the attraction.

The drop now being in the vessel of the root, all the other factors already mentioned have more or less to do with the ascent through the vessels and wood cells of the root, through the vessels and wood cells of the stem and branches, and then into the vessels of the petiole, veins and veinlets of the leaf. From these vessels it is taken up into the active green cells of the leaf by osmotic action. After a time these cells become extremely turgid owing to absorption and other vital activities in the cells, and there is a tendency to relieve this tension by a release of some of the liquid through the sides of the cell offering least resistance, and this is evidently on the side next the air of the intercellular space. Consequently water oozes out into the intercellular spaces and is there taken up by the atmosphere, because when in this intercellular space it is connected directly with the open air through the stomates. But it should also be said that a portion of the water of the drop, and practically of the matter in solution, is used in the green cells. Not necessarily all of the water which is taken in at the root reaches the leaf because a considerable portion may be taken by the various tissues along the way, to supply the losses resulting from drying out. With regard to the root hair itself, a loss of substance to the surrounding soil often results. So that the root hairs do not merely absorb. It is inevitable that they also give out, from the very nature of the process involved in absorption; but this giving out will depend upon the character of the soil water, mainly with regard to its density, and to the substances in solution; and also upon the content of the vacuole of the root hair. The plant overcomes this loss, to some extent, by providing continually a new set of root hairs which contain about

the right quantity of material to produce the maximum absorption and the minimum loss. Moreover the growth of the root in length brings it about that these new root hairs are in a new portion of the soil.

At the other end of the machine involved in transfer, are the guard cells of the stomata whose office appears to be mainly to regulate the size of the opening between them, and thus control the intake and the outflow of air. This outgoing air is laden with water vapor, and this is the water of the soil relieved of its small amount of inorganic matter.

Now for the return system. In the living green cells of the leaf the carbohydrates and other similar compounds are organized out of the inorganic materials, carbon dioxide and water, and these substances, to be transferred, must be in a liquid form, and in order that this liquid may pass from cell to cell by osmotic action it must be an aqueous solution, not an oil or a colloidal substance. The chief force, so far as is known, in causing transfer from cell to cell, is osmotic activity. The condition of the cell sap content is the important factor determining whether the flow be fast or slow, positive or negative. Soon, however, even in the small veins of leaves, the organic liquid is forced into a system of tubes, which might be compared to a number of short pieces of gas-pipe, end to end, but with a porous plate or sieve across at the joints. Through these tubes colloidal or other material may go but slowly. Through the lateral walls of these tubes much material is pressed out into neighboring—very elongated—cells. These are called companion cells, and they aid very materially in the process of transfer. While these substances are being transported from the leaf in the direction of the root, much of them is taken up and used by the living tissue on the way; and often some of them are stored here and there by the wayside. But a large amount must reach the roots to furnish a supply of food. It must even reach the root hairs, because these are dependent upon such matter for a supply of food. The soil water is absolutely of no direct value as a food supply.

The second plant, the pine, differs from the maple in that it has no tubes in its upward system. The current is carried through the wood cells, from one to another, very readily because these cells have in places very large openings from one to another where they lie adjacent to the medullary ray cells, which cells also have large openings to correspond with those of the wood cells. This makes a tolerably direct course for the water upward through the stem. Such structures are peculiar to the pines and other conifers. But for the downward conducting apparatus they have a well defined system of tubes in both wood and bark. Through these tubes is conducted the organized material, part of which is in the form of resin. At certain times of the year much starch is found in the bark of such trees, but later there is little starch and much gum or resin. This gum is made from other organized matter and is secreted in large resin glands in the bark. It is conducted from these resin glands through living cells of cortex and of medullary ray into the resin ducts of the wood. The downward current in conifers therefore differs from that of the maple in that some of the organized material passes down through the wood as well as through the bark. The material from the glands of the bark passes through the living cells of the medullary rays until connection is made with a resin duct in the wood, and from that downward to other medullary rays, where it may be conducted outward toward the bark again. Besides this resin apparatus of the conifers, they have a sieve tube system similar to that of the maple.

In a sunflower the systems are practically the same as that of the maple excepting that as the sunflower is an annual and the maple a woody perennila,

the up-current of the maple may be through portions of the wood which are several years old, sometimes as many as eighteen or twenty. An important exception to the system of which the sunflower has been taken as a type is that which occurs in the pumpkin. Here the backward flow of organized material passes, in part, through a portion of the tissue next the pith as well as through the cortex. There are two general regions through which the organized material flows backwards from the leaves towards the root, one on the outside of the woody fibre, and the other on the inside. Through the woody fibre, of course, the water from the soil passes in an opposite direction, just as it does in the maple or the sunflower.

The corn plant differs materially in structure from the sunflower mainly in that its conducting fibres are scattered (in cross section) throughout the whole stem, while in the sunflower they are in one concentric ring. But these two stems are similar in that the up conducting portion of the fibre is on the side of the fibre towards the center of the stem, while the down conducting part lies on the opposite side. It can scarcely be said that any one of these four types of system is better adapted to the conducting of liquids than any other, though from a mechanical point of view there might seem to be a choice. The up system in the maple as compared with the pine would no doubt be capable of transmitting a greater amount of liquid in a given time, but the leaves of the pine need (for a given weight of leaf substance) a great deal less water than the leaves of the maple. A maple requires about 75 liters of water where the pine requires only about 7 liters.

One other special instance of conducting vessels should be mentioned. A considerable number of plants produce a milky juice, e. g., the dandelions, the dogbanes, the spurges. Such plants have a peculiar system of tubes situated in the cortex. In these is found a sort of an emulsion composed of oils, gums, water and other material, and sometimes starch grains. These tubes are sometimes branched and often they anastomose, but they are extremely long, forming a well defined means of transportation of such material as may be in them. The general course of the current in these tubes is towards the root, and the material is likely of such a nature as may be drawn upon by the plant for food when necessary. Some say that the latex (material in these tubes) is not a reserve food, but the weight of evidence and of probability is against such a conclusion.

In general, there are special portions in leaves of plants which are adapted to the liberation of water. When the stomates are inactive during the night the stomatal openings are small or closed entirely, and as such forces in root and stem are as active in transporting water as in the day time, there must be some other means of outflow than stomates. Many plants have such structures, and these are called water-pores. They occur commonly on the tips of leaves of grasses, notably corn, wheat, oats, barley, june grass and the like. They occur also near the ends of the chief veins or veinlets in such leaves as grape, strawberry and nasturtium. On such plants small drops of water may be seen on the parts mentioned, in early morning. This has been called dew, but it is really water which has passed through the plant and contains inorganic substances, as well as, occasionally, small amounts of organic matter. It is not a deposit from the air as is generally supposed.

Just as there are special portions of plants adapted to the liberation of water, so there are also specialized parts adapted to check the flow of water. Downy coverings, oily or waxy surfaces, sunken stomata are thought to be such adaptations.

A plant like the grape vine or Boston ivy which has a large number of

leaves in comparison with the size of its stem, has conducting vessels of enormous size, enabling the plant to supply through its small and long stem the needs of the leaves. Many roots are similarly developed. The elm root, well known to the youthful would-be-smoker, has vessels similar to those of the grape stem. These vessels, as are also those of other stems, are modified cells, which by losing their intervening end partitions, have been thrown into one long canal which has been termed a vessel, and hence the name vascular plants as applied to all such as have vessels.

The amount of water liberated by a plant may be realized by giving some figures. A birch tree having about 200,000 leaves gives out about 400 liters (125 gallons approximately) in 24 hours. A sunflower of good size about one gallon in three days, and an acre of cabbage about 550,000 gallons in four months. But certain plants, as has already been pointed out, differ widely from others in amount of water liberated, e. g., a beech tree gives out about ten times as much as a spruce, the weight of the leaf being used as a basis for calculation.

To realize more fully the operation which this loss of water involves, let us give one special instance: The amount of air required to carry off the water given out by transpiration is enormous. At a temperature of 82 F., an oak requires about one million cubic feet of air per day, a sunflower 1500 cubic feet per day, and an acre of cabbage about 25 million per day of 24 hours. These figures are calculated from the amount actually transpired, and from the amount of water vapor in suspension in air at a given temperature.

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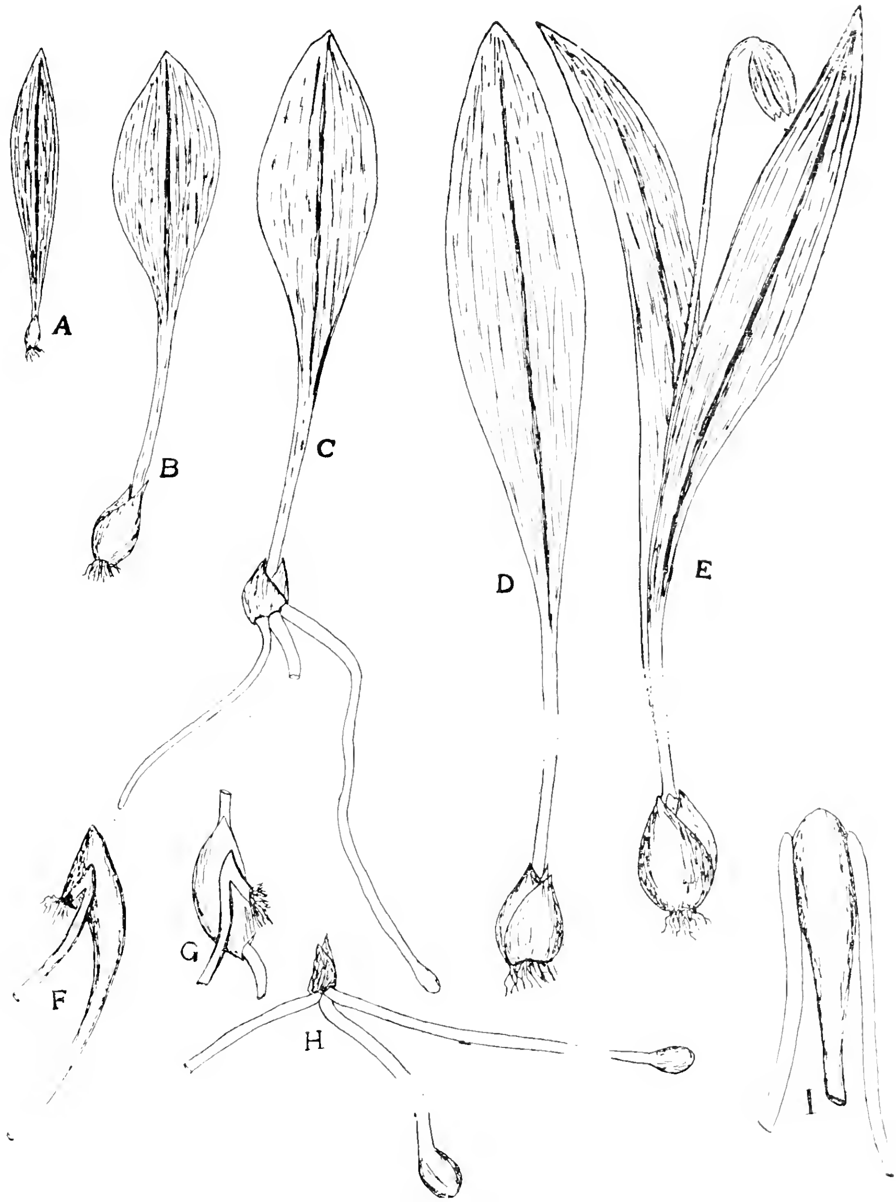
VEGETATIVE REPRODUCTION IN ERYTHRONIUM AMERICANUM.

J. B. Dandeno.

This plant has certain peculiarities about its vegetative habit which entitle it to some special attention. It is not intended to go into the whole life history in minute detail, because much of it is not different from that of others of its relatives. It is one of the commonest of our spring plants, and one which, in the struggle for existence, has acquired the habit of making its year's food, flowering and seeding, during the months of April and May, in this locality. And this does not imply that it requires two full months to accomplish this. In one season it appears above ground on April 20th and disappears entirely from above ground on May 28th. This period constitutes what might be called its period of vegetation, or its life period.

Very few seeds of this plant seem to set, and only a few of these can ordinarily be made to germinate in the laboratory, so that the plant seems to be losing its power of propagation by seed. Whether this be so or not, it has an excellent system of vegetative propagation.

On examining with the aid of a spade in early spring when the plant is in leaf, a large amount of material showing the underground parts, an interesting point relative to the direction of growth of the stem is quite apparent. Having first started from seed among the humus of the woods, or along fences it produces a minute narrow-leaved plant which develops into a form as represented in figure A. The leaf petiole is comparatively short, for the bulb is formed quite near the surface. This bulb becomes in one season about 5 mm. long by 3 mm. wide, and this is the first year from the seed. This bulb, during the following season, sends out from one to five underground stems, each spreading out and pursuing a course not horizontal but slanting downwards. While this is going on, one leaf is sent up into the air. This leaf is larger, broader and has a longer petiole than that of the previous year (Fig. B) The following year the bulb sends out underground stems—three or four in number. These grow downwards, also in a slanting direction, and the bulb is developed on the tip of each. At the same time but one green leaf is sent up into the air (Fig. C). In this year the bulbs at the ends of the stems become particularly large, and the parent bulb dwindles away, becoming almost entirely absorbed. This is generally not the case in the bulbs of any other year. At the end of the fourth year the bulbs are as deep as they ever become. So that the deepening process is accomplished during the second, third and fourth years. During the fourth year the bulb develops to a very considerable size, but there is only one leaf. During the fifth year the plant sends up two foliage leaves and also one flower stalk, but no underground stems. Nor does it ever after this develop deepening stems, but goes on from year to year by producing from one to three new bulbs just in immediate connection with the old one, in a similar manner to that of the common onion. In the following years it produces a flower about every other year, of course from the same location in the soil, so that whatever creeping the plant does is accomplished during the first four years from seed. The length of the petiole varies necessarily with the depth of the bulb from which it grows.


A
B
C
D
E
F
G
H
I

One of the most remarkable points about this plant is its peculiar method of securing a deep foothold in the soil. Ordinarily stems have a tendency to grow in a direction away from the earth, hence we see so many plants assuming an erect position. A considerable number of plants produce their stems in a horizontal position, especially is this the case with such as produce rhizomes, but with the Erythronium the stem actually grows downward. The advantage of such a growth to the plant is, of course, quite apparent. The flower gatherer in the spring may pluck the flowers of this plant but she never gets the bulbs unless she have a spade along, consequently the bulb remains; and though the plant is weakened considerably by the production of a flower, yet the two large leaves have been so active that the old bulb is still quite well stored with starch, and, though it does not send out other leaves the same year, it will send out one, or perhaps more, one-leaved (Fig. D) plant the following year. The crop of seed is destroyed but the vegetative apparatus is in no way injured by the gathering of the flower. In fact if only the flower were gathered, and the two leaves left, the vegetative power might be actually increased. The ordinary gathering of flowers, then, does not materially affect this beautiful spring plant, and it is one of the three most attractive of the earliest spring plants—Hepatica, Claytonia and Erythronium.

From fertile seed, therefore, one plant results the first year, two or three the second, six to nine the third, and eighteen to forty-five the fourth. After this the plant may go on indefinitely, though confined to the one situation. The peculiar growth of the stem is illustrated in figure F. Figure I is a back view of figure F. For a very short distance, perhaps two or three mm., the stem grows upward but soon makes a sharp turn (figures F and G), and then grows downward, not vertically, but in a slanting direction. In the flowering year this turn is not made, the plant stem acting as an ordinary erect stem.

The reserve material of this bulb is starch, and this reserve material is rarely entirely used up by the plant, even when it would seem, in the natural order of things, to be no longer required.

The underground stems of this plant show a very peculiar condition in cross section (figure 10). There is a very peculiar crescent-shaped opening which persists throughout the whole stem. The only interpretation I can put upon it at present, is that it may be a rudimentary condition of a leaf-sheath encircling the stem—the slit being the only place where the sheath does not fuse entirely with the stem. A section through a bulb developing on the end of one of these stems shows the slit to become a circular opening (figure 11) through which it may be supposed the new young stem to pass. Sections through older bulbs seem to confirm this view (figure 13). One point seems, however, to be against this. Quite frequently the curve of the slit is far from parallel with the circumference of the stem, presenting an appearance as shown in figure 12. In these underground stems, the fibro-vascular system is very rudimentary, so that it is impossible to determine whether the bundle system pertains to leaf or stem, consequently the internal structures do not throw much light upon the question. A section through a portion of the stem immediately back of the bulb presents the view of a larger and longer slit (figure 14).

It seems as though both leaf and stem grow together, the tissue being indistinguishable for practically the whole distance, and from the appearance shown in figures 11 and 12, it might be considered that the stem actually was one long node of what might be called embryonic tissue. The whole of

figure 11, excepting that indicated by "g" is *apparently* leaf. Various sizes of opening "c" can be seen, leading one to suppose that "g" is only a modification of "c," and the opening through which the young stem grows.

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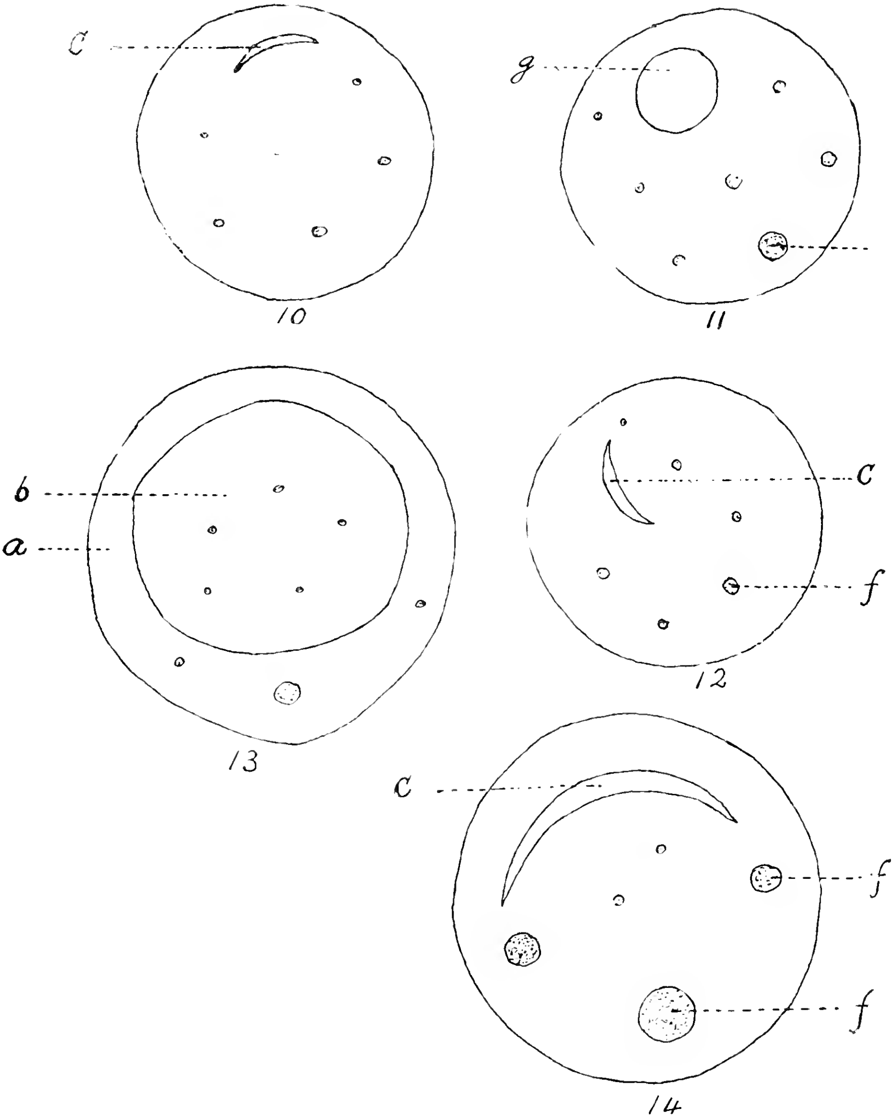
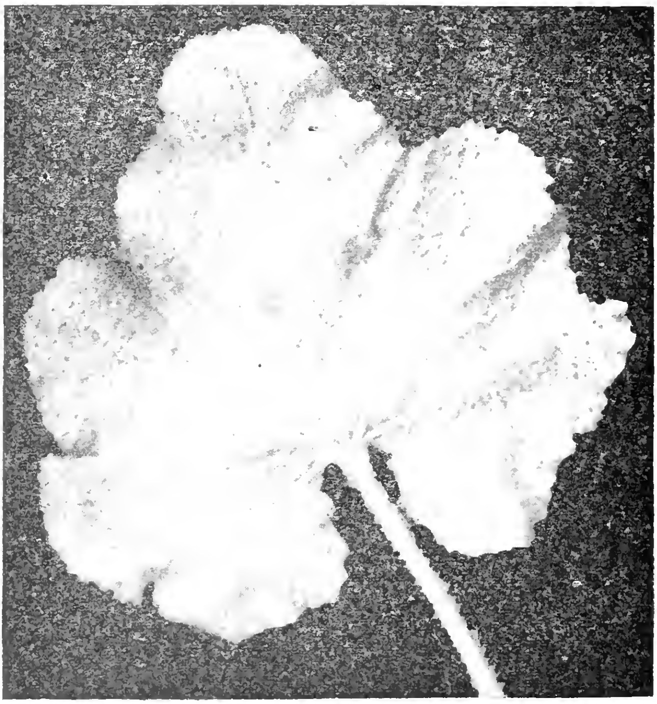


In figures 10, 11, 12, 13, 14, *a* signifies a leaf-sheath, *b* young stem, *c* a crescent-shaped opening through which the stem may grow *f* a fibro-vascular bundle, *g* circular opening corresponding to *c*.

THE LIFE HISTORY OF PUCCINIA MALVACEARUM.

J. B. DANDENO.

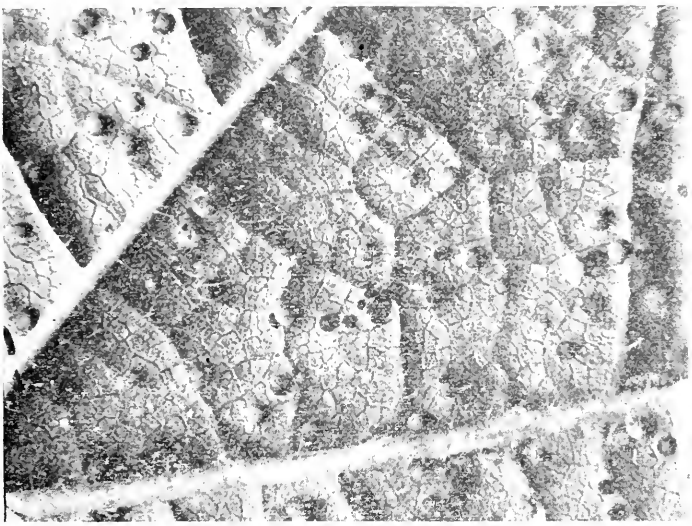
This fungus parasite arouses considerable interest from the fact that it produces, so far as at present known, no aecidial spores, no uredo spores and no spermatia. Until two years ago the writer was not able to find this rust until about the middle of September, and considerably later than this in some seasons. But when once it did appear, it seemed to spread with astonishing rapidity, persisting until the snow fell, away on into November, as long



as the host was able to withstand the frosts, and this is quite late with the common mallow, upon which host the rust is very abundant. From the fact that the rust appeared so suddenly, and so late in the season—especially so in the common mallow—it was thought that some other stage of this rust might possibly exist on other host plants. Investigation was started three years ago to discover, if possible, how the fungus passed the winter, and also if the sporidia could be made to inoculate other plants. Unsuccessful attempts were made on several species of each of the following families: Compositae, Labiatae, and Papilionaceae. It was supposed that the fungus

might pass the winter in the mycelium embedded in the embryo of the seed, and when the embryo began to grow, the fungus might be expected to grow with it. Following this suggestion, many affected seeds were collected and planted, then kept under conditions unfavorable to inoculation from external sources, but in no case did the rust appear on seedlings grown from affected seeds. It is stated by Massee that it often passes the winter thus, i. e., in the embryo of the affected seed, but this was not borne out by the experiments in connection with this paper.

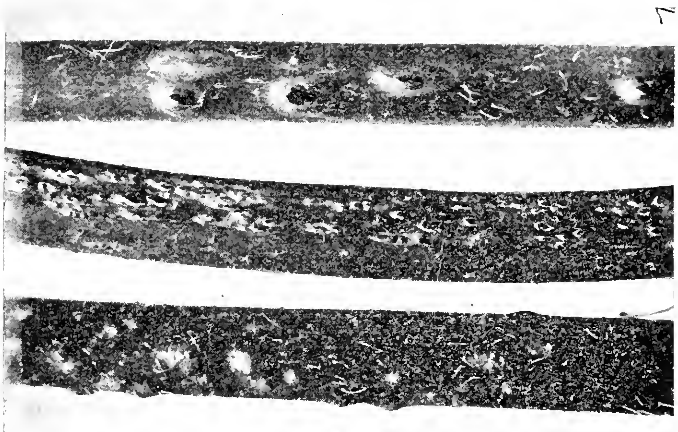
Massee also states that the teleutospores produced late in the season acting as resting spores, and then germinate in spring, thus tiding the fungus over winter. A number of observations and tests were made to sustain, if possible, this view, but without success. Very favorable conditions rendered a minute study of this point comparatively easy. There was an immense plot of mallows quite near the laboratory, and these were every year badly infested with the rust. It was so abundant, and the mallows so large and luxuriant, that material could always be obtained throughout the winter. Many of the plants wintered as perennials, so that it was possible to get living



tissue at any time. None of the old spores could be got to germinate. In fact most of them had germinated and nothing remained but the walls of the old teleutospores. Those which had not germinated seemed dead. These were the latest of the season and should, according to Massee, germinate, but they did not. An extra effort was made in early spring to secure some which would germinate, because at this time of the year the teleutospores of many other species of rust send out a germ tube quite readily. None of the mallow rust showed any signs of life, although they are unusually favorable forms for the illustration of sporidia production. The idea of teleutospores wintering over had to be abandoned. One attempt among many might be mentioned to show that teleutospores did not survive the winter. A large amount of dead leaves and stems of affected mallows containing countless numbers of teleutospores were strewn the following spring among

certain patches of mallows which were, to all appearances, free from the rust. If the teleutospores had survived the winter, it was thought that infection of these fresh young mallows must result. The infected litter did not seem to produce any result whatever. The wintering over is accomplished in another way.

On examining mallows very early,—about April 10—in 1906 and 1907, well-developed teleutosori were found on leaves and petioles. These mallows had wintered over as perennials in the shelter of the grass alongside of a hedge, and also alongside some of the college buildings, so that practically as soon as the mallow commenced to grow—and that was almost as soon as the snow disappeared—the teleutosori were plainly seen. The spores from these sori germinated readily when taken into the laboratory and placed under favorable conditions there. It seemed apparent then that the fungus wintered in the living portions of such affected mallows as withstood the winter. Still it seemed curious that the parasite being able to withstand the winter in such a way as to have such an early start in spring, should not become so abundant during summer as it does in the fall. On examining, from time to time, those mallows which were infested in April, it was found that the fungus spreads only very sparingly over the other leaves of the same

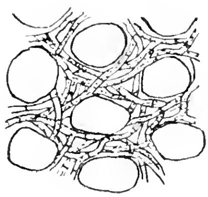


plants, or over leaves of neighboring plants; and in July and August it seemed almost to disappear, then to recur about September 1st, on the hollyhock, and about October 1st, on the mallow and other species of the same family. The reason for this slow development of the fungus in summer, and its consequent rarity at this time, is not very apparent, yet from the fact that it does better in cool weather it may be that temperature and moisture are important factors; but these can scarcely be the only factors. It may be that an enfeebled condition of the host plant is also no unimportant factor.

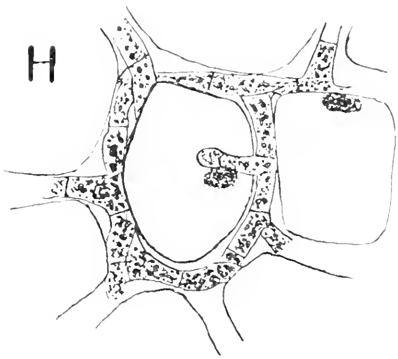
This rust was found in the Botanic Garden here on species of the following genera of the mallow family: *Malva, Althaea, Malvastrum, Sidalcea, Malope, Abutilon*, but not on *Hibiscus, Sida, Napaea, Anoda*, though in the gardens all ten genera were growing practically side by side. With those plants upon which the rust was found, it was very abundant, especially in the fall of the year 1905.

An idea of the general habit of the parasite may be obtained from photographs I, II, III.* The under side of the leaves become "peppered" over by a large number of the sori, each of which being one or two mm. in diameter and elevated above the surface. (See photograph II.) The disease is very much localized, that is, it is confined to a small area immediately in connection with the sorus. This is especially true of the leaves, but on the petioles and stems the sori may be much longer than broad and running some distance up and down the petiole and stem from the point of infection The sori on the petioles and stems are covered by the epidermal layer of the host for a longer time than is the case with the sori on the leaves. (See photograph III.) Upon the petiole the mycelium works under more readily and more extensively, giving the sorus more strikingly the appearance of an eruption.

K



H

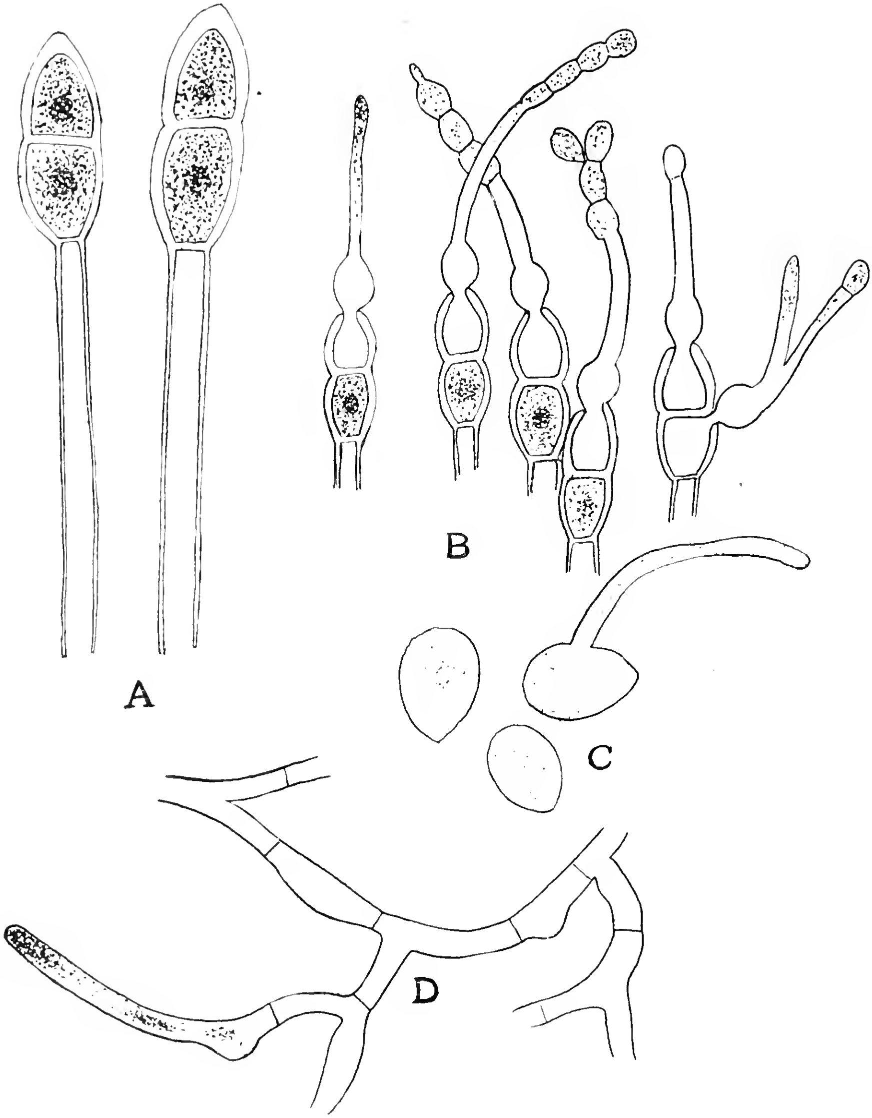


H. Cells of mallow stem as seen in cross section, taken from cortical parenchyma showing the large mycelium and haustorium.
K. Cells from same stem taken from a portion of tissue lying close in upon the strands of collenchyma; mycelium much smaller than in "H," and apparently no haustoria.

The teleutospore germinates very readily as soon as mature both on the sori while on the leaves, and on a moist slide, if the spore be in the air and a portion of the tissue of the host attached. The promycelium and the sporidia very rarely develop while immersed in water, or when in a Van Tieghem cell. The promycelium has a strong tendency to grow away from the teleutospore, and in the same direction as the teleutospore developed. Consequently a sorus of germinated spores presents the appearance of a gray or whitish mass due to the promycelia extending out from, and nearly covering, the sorus.

Examples of germinating teleutospores and of the formation of sporidia may be seen in figure B. The sporidia themselves send out germ tubes quite readily in water. This is shown in figure C. Immediately outside of the germ pore of the spore, the promycelium swells out almost to a spherical form as shown in figure B. So far as the writer is aware this is peculiar to the mallow rust. What its significance is can scarcely be conjectured.

* Photographs were made by Professor Pettit.



A. Teleutospores x 600, optical section showing relative length of pedicel.
B. Teleutospores germinating, producing sporidia—one to four—at the end of the promycelium x 350, optical section.
C. Sporidia, one of them germinating x 1000.
D. Mycelium teased from the leaf of mallow; granular and yellow towards the end of the hypha x 500.

Artificial inoculation is comparatively easy to carry out in the laboratory. Sori develop in six to ten days after inoculation with sporidia. Cool weather seems to be favorable to the development of this fungus.

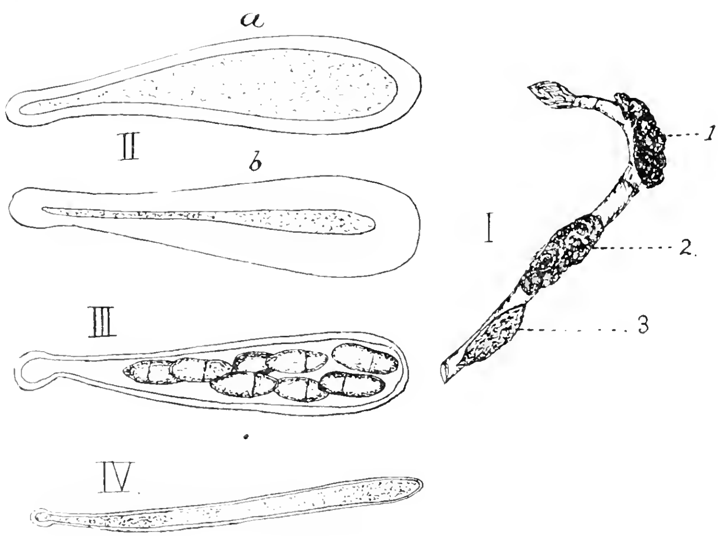
In the portions of the tissue where the mycelium works, be it leaf, stem or petiole, it develops mainly between the cells which become pushed apart so that the distance from one cell cavity to another is about as great as the diameter of the cell (figure K). Once in a while an haustorium may be seen (figure H), but the mycelium is intercellular.

Agricultural College, Mich.

NOTES ON THE BLACK KNOT OF PLUM.

J. B. DANDENO.

After many unsuccessful attempts to obtain ascospores from the black knot of plum, it was thought worth while to make some special investigation into the cause. Sometimes success was met with, but, for the most part, the material either contained no mature perithecia, or the perithecia were empty. The fact of the matter seems to be thus: It takes about three years (after infection) to produce mature perithecia, and once having been produced, the asci are disseminated, but the old knot remains on the twig, appearing just as it did before the asci had gone. To collect material showing asci and ascospores, the material has to be gathered from the third year's growth. This growth is nearest the apex of the twig, as the fungus works down towards the trunk (figure I). The three years' growth can readily be made out by the appearance of the affected twig (figure I, 1, 2, 3). The first infection and the first year's growth is shown at 1, the second year's growth at 2, and the third at 3. At 2 and 3 are no perithecia, though in 2 may be seen well rounded knobs similar to those seen on mature knots, but no mature perithecia.



To obtain mature ascospores material had to be collected in April. That collected earlier in the season showed asci as in figure II. Many asci had gelatinous walls, some of which were exceedingly thick (II b). Many of those asci which have such thickened gelatinous walls seem never to produce spores. Those which do, seem to become thin-walled later, appearing as though the material was used up in developing the spore content (figure III). The paraphyses (figure IV) are not very abundant—about one to four of the

asci; and only about half of the asci seem capable of producing spores. The other half remain similar to that shown in II b.

From inoculation experiments with the conidia it would seem as though they were not very active as infecting agents. From thirty inoculations with conidia not a single infection developed; but from the same number of inoculations with ascospores, four succeeded. The attempts to inoculate with conidia was made in September, and with ascospores in May. The second year after these attempts were made the whole plum orchard was uprooted, so these experiments were terminated more suddenly than was anticipated. At all events it seems tolerably clear that in any case, whether by conidia or by ascospores, infection is not easy to accomplish. Only two methods were employed, one by puncturing the living cortex with a needle and inserting some spores, and the other by placing spore material into the crevices, in and around the bud, then placing a few drops of water in connection with the inoculating material.

PLANNING AN EXPERIMENT TO SHOW TO WHAT EXTENT BUMBLEBEES AID IN POLLINIZING RED CLOVER.

W. J. Beal.

Darwin covered 100 flower-heads of red clover by a net and not a single seed was produced, while 100 heads growing outside yielded by careful estimate 2,720 seeds. He concluded: "It is at least certain that bumblebees are the chief fertilizers of the common red clover."

During eight years at the Agricultural College I covered clusters of flower-heads of red clover by a net, and when harvested never failed to secure some seeds. Darwin's conclusion was too sweeping; it was very likely true of the locality and the season in which he made the experiment.

Suppose we wished to secure definite results as to what extent the visits of bumblebees increased the yield of clover seeds. Wouldn't you select a number of plants in flower near each other, cover a portion of them with nets and leave a like number uncovered? There are at least two reasons why such a test might not be reliable. 1. Bumblebees might be scarce or absent altogether from the plants experimented upon, hence would have little or nothing to do in pollination. 2. Do we know that heads of two different plants would yield an equal number of seeds? I will illustrate this second point by some experiments which I made about 25 years ago. In September, five or six plants apparently nearly alike, and within a few feet of each other, were selected for a test. None of them had been covered by nets. Fifty heads were selected from each plant and the seeds shelled out carefully with the following results: 1260, 1275, 1460, 1485, and 1820. It will be seen that 50 heads from plant number 5 contained about one-third more seeds than 50 heads from plant number 1. At the same time in another place, 50 heads selected from one plant yielded 2290 seeds, nearly twice as many as were produced by plant number 1 in the first lot. Further, suppose some one says that he thinks a net placed over the heads shading them somewhat is a hindrance to producing seeds, what can the experimenter say in refutation to this criticism?

In my later experiments made about 1882, I selected a number of thrifty spreading plants, dividing the top on a north and south line, turning half the top to the east and the other half to the west. Over each half independently was placed mosquito netting held up by stakes and spread out four or five feet in diameter. Under the net covering one-half nothing further was done, while under the other half several bumblebees were placed, and others for several days were collected and placed inside, and not only placed inside, but were seen to be busy passing from flower to flower. So far as the experiments showed for eight years, those flowers visited by bumblebees yielded about four times as many seeds as did those covered by nets. Nor are all of these precautions sure to bring accurate results. We are in doubt as to what extent the bumblebees placed under the mosquito netting performed their work effectually. Again clover blossoms were examined now and then and small crawling insects known as thrips were seen briskly going from place to

place, in and out of the flowers. It is possible that there were more thrips under the net on one side of the plant than on the other.

For 35 years heads of clovers to some extent have failed to produce a good crop of seeds, in some cases producing very few seeds, from the effects of the clover seed midge. To what extent the results were modified by midge in my experiments I am unable to tell you. Clover plants, bumblebees, thrips, and perhaps others not discovered, are complex living organisms, and are liable to tamper in some way with any experiments we may make with red clover.

Agricultural College, Mich.

THE BUD SCALES OF CELASTRUS AID THE VINE IN CLIMBING.

W. J. Beal.

On a southern slope in our botanic garden, I have for twenty years grown three species of Celastrus, our native C. scandens, and two others, all behaving much alike. Each woody vine has a small pole to climb that is often supplemented by small sticks nailed on to occupy the place of short upright branches. Celastrus paniculata is the one selected for most of the observations. Like other twiners, this one has slender branches which lean over and away from the pole that sustains the main vine. They twine in the direction opposite the course of the sun and a branch may make a growth of five to eight feet in one season, the base of which is less than a fourth of an inch in diameter. Only about two feet of the apex is capable of swinging about at the top of a neighboring hemlock tree. The young tender apex while in the air is irregularly coiled or curved like a sickle or cork screw with a coil two to four inches across.

The point of special interest is now about to be described. The sharp outer bud scales 2–4 mm. long with diverging recurved tips begin to harden when four inches to a foot back of the growing apex of the vine, and late in July this hardening is apparent to near the apex.

I thought at first the two outer lateral scales were morphologically stipules, but this is not the case. Beneath a bud is a pair of very delicate fringed stipules for nearly every leaf. One has only to run his hand loosely from the base towards the apex of a young vine to be impressed with the importance of the bud scales as an aid in climbing. The tip of a vine not finding a support, often recoils on itself making an ovate loop three to four inches in diameter. It is not unusual for two to five young branches to wind about each other, forming a loose cable from which slender young branches may extend the following season.

Agricultural College, Mich.

PHYLLODY OF THE STAMENS AND PETALS OF NYMPHAEAE (NUPHAR) ADVENA.

W. J. Beal.

On July 20, 1906, at Alward lake, about ten miles north of Lansing, I discovered some flowers of the above named species, one of which was unlike anything I had ever seen or had called to my attention.

Thirteen of the outside parts of the flowers apparently consisted of the sepals, possibly some of them including the petals. These are much like the floral envelopes though rather smaller and less colored than those of a normal flower. Within these are forty-three pieces, probably the petals, from 3–6 cm. long, each with the apex ovate or elliptical more or less the form of the bowl of a narrow spoon. The margins and the central portions are more or less yellow in color. Inside of these are 247 stamens from 10–15 cm. long; the filaments oval in section and 2.5–4 mm. wide. The oval, "spoon-shaped" apex is usually involute 1.5–2 cm. long by 7–13 mm. wide, with margins and midrib often yellow.

The compound pistil consists of sixteen carpels united, apparently much like those of a normal flower, excepting that in place of stigmas, we find sessile, involute objects much resembling the apex of the stamens. There are no ovules.

A normal flower collected in the same lake contained 225 stamens, while this peculiar one contains 247.

Normal flowers of the species contain six sepals, petals and stamens indefinite, numerous carpels 12–24.

Vegetable Teratology by Maxwell T. Masters contains an illustration of a flower of Petunia in which in place of each stamen is a slender petiole bearing a small oval leaf.

Agricultural College, Mich.

FOMES PINICOLA FR. AND ITS HOSTS.

L. H. PENNINGTON.

It was the pleasure of the writer to spend the summer of 1906 with Mr. C. H. Kauffman in the study of the fungus flora of Nőrthern Michigan. We left Ann Arbor July 7th and went directly to Sault Ste. Marie where we remained ten days. We then spent five weeks in Keweenaw Peninsula with Houghton as our principal station, one week at Munising, and two at Marquette. On our return we stopped for a few days in the vicinity of Petoskey.

At all the places which we visited the forests consist of both hardwoods and conifers, either growing together or in societies[1] not very widely separated from each other. The principal hardwoods are the Hard Maple, Beech, Yellow Birch, White Birch, Red Oak, Balsam, Poplar, American Aspen, Black Ash, and the Hop-hornbeam. Of these the beech was not found at Houghton or Marquette, but it is very abundant at the other stations. The principal conifers are the Hemlock, the White, Norway, and Jack Pines, White and Black Spruce, the Balsam Fir, the White Cedar and the Tamarack. The Norway and Jack Pines were seldom seen except at Marquette.

Although hardwoods and conifers were often found growing together, the same fungus was seldom found upon both. *Fomes salicinus (Pers.) Fr.* was found upon Hemlock and Balsam Poplar at Marquette; *Poria subacida Pk.* upon Hemlock, Spruce and American Aspen; *Polyporus sulphureus Fr.* upon Red Oak and Hemlock; *Polyporus resinosus Fr.* upon Maple and Hemlock. The most notable instance, however, was the occurrence of *Fomes pinicola Fr.* upon the hardwoods and conifers.

Fomes pinicola Fr. was found to be the most common of the larger fungi that infect the conifers. At practically every place that we visited it was found upon Hemlock, White Pine, Spruce and Balsam Fir. At Petoskey it was found upon Tamarack also. In the vicinity of Ann Arbor the Tamarack seems to be its only host. The fruiting bodies were almost always found upon dead trunks, very often after the wood had become much decayed. When upon stumps or standing trunks they were observed to be near the base usually only a few inches above the ground. Upon prostrate trees they were scattered along the trunk and everywhere growing most abundantly in moist situations.

The pileus is usually concentrically sulcate (sometimes even) and zonate. The marginal zone is yellow varying from white when the annual growth begins to a dark yellow or red by the time the next annual growth appears. The second zone is a dark red and the rest of the pileus is black. The shape, which depends largely upon the rate of growth, varies from a hoof or cushion shape when growth is slow, to applanate forms when growth is rapid. The substance and pores vary from white to ochraceous or straw color. The pores, which are very small, are not closed or stuffed in young stages so that it is difficult to determine whether a specimen is mature or not. It is impossible to determine the condition of a plant in this respect after it has been

[1] Davis, C. A., Formation, Character and Distribution of Peat Bogs in Northern Michigan, Report of State Geological Survey for 1906, p. 191.

dried unless a microscopic examination is made. Specimens, collected at different times and at different stages in their growth or under different conditions of growth, have respectively all the characters of *Fomes pinicola Fr.*, *F. ungulatus Schaeff.*, and *F. marginatus Fr.* There are also intermediate forms between these species. Fruiting bodies in a growing condition were found in July, August and September, and again in March and April in the vicinity of Ann Arbor. No specimens with spores were found, however, and the writer has, as yet, found no record of when spores are produced.

Fruiting bodies of this fungus were also occasionally found upon the hardwoods, Hard Maple, Beech, Yellow and White Birch and Balsam Poplar. Upon these five hosts the fruiting bodies were not unlike those upon the conifers, except that they were somewhat smaller. Some, however, lacked entirely the yellow and red zones upon the pileus.

Upon Presque Isle near Marquette were found the most favorable conditions for the growth and spread of woody fungi. This is due to several causes. It has been the policy of the authorities to have few if any of the dead and dying trees removed, in order that the place may be kept in as wild a state as possible. In addition, however, to the trees which are normally killed by shading or injured by storms, some have been cut and left lying upon the ground, and a great many have been injured by visitors to the park. As there are also many species of trees growing together upon the island, the usual hosts and favorable conditions are furnished for many of the wood destroying fungi. Among the trees the Balsam Poplar seems to have once been very common there. Now, however, a great many of them are dead, and an examination showed that by far the most common fungus upon these dead trunks was *Fomes pinicola*. Some of the fruiting bodies were not unlike those upon the conifers, while some of them were entirely destitute of red and yellow colors upon the pileus, having a dusky black pileus with a white margin. There were also intermediate forms which had a little red or yellow between the white margin and the rest of the pileus. One series of specimens ranging from those with decided red and yellow zones to those entirely destitute of them was found but a few inches apart upon the same dead Poplar. Another series which illustrates the same thing was found upon a dead Hemlock. It is therefore evident that these are not morphologically different forms. It is never-the-less remarkable that this fungus, which ordinarily grows upon coniferous trees, should be epidemic here upon the Balsam Poplars. This is especially so when we consider that other species, such as *Fomes igniarius Fr.*, *F. salicinus Fr.*, and *Polyporus adustus Fr.*, which commonly attack the poplars, were found no more frequently here upon the Balsam Poplar than in other places where poplars abound. At no other place was *Fomes pinicola* found upon a poplar.

No one seems to have recorded the occurrence of this fungus upon poplars and but few have recorded it for other deciduous trees. Saccardo[1] says that in Europe it is very common upon the pines and rarely found upon birches. Peck[2] found it very variable upon the trunks of conifers, and he also noted a form upon the deciduous trees, less common and destitute of the red and yellow colors found on those of conifers. Atkinson[3] says: "I have not found any record of *Fomes pinicola* on broad leaved trees. I have, however, found it on three different species in the Adirondack Mountains, on beech (*Fagus*

[1] Sccardo, Sylloge Fungorum Vol. VI, p. 167.

[2] Peck, C. A., Report of State Botanist, New York State Museum Report, 1900.

[3] Atkinson, Prof. G. F., Studies of Some Shade Tree and Timber Destroying Fungi, Bull. 193, N. Y. Exp. Station, 1901.

ferruginea), birch (*Betula lenta*), maple (*Acer saccharum*)." Murrill[1], who considers *Fomes pinicola Fr.*, *F. ungulatus Schaeff.*, and *F. marginatus Fr.* as one species under the name of *Fomes ungulatus Schaeff.*, says that it is found abundantly upon conifers and rarely upon deciduous trees standing near its usual hosts, and that beech, elm, maple, and birch are known to have been attacked by it in American and European forests where conifers abound.

From the observations that have been made it is evident that *Fomes pinicola Fr.* is a very common fungus on the coniferous trees of the state.

It sometimes attacks Hard Maple, Beech, Yellow and White Birch, and Balsam Poplar also.

Upon Presque Isle it has so adapted itself as to become epidemic on the Balsam Poplar.

The fruiting bodies vary in shape depending largely upon the rate of growth, and the colors of the pileus are different at different periods in the development of the same fruiting body.

In some instances on deciduous trees the pileus may be entirely destitute of red and yellow colors.

Ann Arbor, Mich.

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[1] Murrill, W. A., Polyporaceae of North America, Torr. Bull. No. 30, 1903, p. 228.

UNREPORTED MICHIGAN FUNGI FOR 1906.

C. H. KAUFFMAN.

The additions to our mycological flora for the year were mostly obtained in the upper peninsula. The species mentioned, along with a great many plants previously reported, were the result of a ten weeks' stay at various points along Lake Superior. Sault Ste. Marie, Houghton, Isle Royale, Marquette and Munising were made the bases around which the collecting was done. Special attention was paid to the Basidiomycetes, and this, with a season that was drier than the average, accounts for the few reports of other groups.

A considerable number of plants remain undetermined, and will have to be reported later. As in my previous annual reports, no effort is made to give the synonymy; it is assumed that the only possible starting point for a report of this kind is to determine by the best methods within reach whether the plant in question is the one considered so by the author who named it; whether other authors had named it before is a question outside of our immediate interest in making out these reports, and assuming that our diagnoses under these conditions are correct, we refer to another place or to other men the task of unraveling the synonymy.

A fuller account of the whole flora of this region will be given in connection with a report to the State Geological and Biological Survey, under whose auspices the work was done.

Mr. L. H. Pennington ably assisted in gathering the material, and Prof. C. H. Peck lent his aid in his usual generous manner.

ASCOMYCETES.

Helvellaceae.

Helvella Stevensii Pk. Ground. Detroit, June, type material collected by Dr. R. H. Stevens.

BASIDIOMYCETES.

Hydnaceae.

Hydnum aurantiacum Pk. Ground. Detroit, Aug. 27, 1905, fide Pk.

Hydnum Kauffmani sp. nov. Pk. (in ed.) On cottonwood trunk, Marquette, Aug. 27. Collected by L. H. Pennington.

Thelephoraceae.

Asterostroma corticolum Mass. On white spruce. Marquette Co. Aug. 31, fide C. H. K.

Craterellus clavatus Fr. Ground, hemlock woods. Bay View, Mich. Aug. 23, fide C. H. K.

Stereum rugosum Fr. Rotten wood of maple. Marquette Co. Sept. 3, fide C. H. K.

Stereum tuberculosum Fr. Houghton Co. Aug. 15, fide Pk.

Polyporaceae.

Boletus badius Fr. Hemlock and birch woods. Houghton and Marquette Co. July 26, fide C. H. K.

Polyporaceae—Continued.

Boletus chromapes Frost. Hemlock and maple woods. Houghton and Marquette. July 14, fide C. H. K.

Boletus eximius Pk. Hemlock woods. Houghton Co. July 25, fide C. H. K.

Boletus luridus Schaeff. Balsam, hemlock and spruce woods. Chippewa Co. July 11, fide C. H. K.

Boletus pachypus Fr. Hemlock, balsam and spruce woods. Chippewa Co. July 11, fide C. H. K.

Boletus Ravenelii B. & C. Oak and maple woods. Marquette Co. Aug. 27, fide C. H. K.

Boletus separans Pk. Oak and maple woods. Marquette Co. Sept. 6, fide C. H. K.

Boletus subglabripes Pk. Marquette Co. Sept. 1, fide C. H. K.

Boletus versipelles Fr. Balsam and hemlock woods. Chippewa Co. July 11, fide C. H. K.

Fomes roseus (A. & S.) Fr. On black and white spruce. Houghton Co. Aug. 11, fide Pk.

Fomes salicinus (Pers.) Fr. On hemlock, balsam poplar and yellow birch. Marquette Co. Sept. 2, fide C. H. K.

Polyporus aurantiacus Pk. On white cedar. Marquette Co. Sept. 5, fide Pk.

Polyporus aureonitens Patoull. & Pk. On yellow birch and alder. Marquette Co. Aug. 27, fide Pk.

Polyporus cuticularis (Bull.) Fr. On black ask. Washtenaw Co. Oct. 15, fide Pk.

Polyporus guttulatus Pk. On ash. Washtenaw Co. Oct. 10, fide Pk.

Polyporus hispidellus Pk. On white cedar. Isle Royale. Aug. 11, fide Pk.

Polyporus lacteus Fr. On alder. Houghton Co. Aug. 10, fide Pk.

Polyporus osseous Kalchbr. On white pine. Houghton Co. Aug 15, fide Pk.

Polyporus Weinmanni Fr. On hemlock. Houghton Co. Aug. 8, fide Pk.

Polystictus pseudopergamenus Thum. On birch. Marquette Co. Aug. 30, fide Pk.

Polystictus velutinus Fr. On rotten wood, fide Pk.

Trametes abietis Karst. On balsam fir and black spruce. Houghton and Marquette Co. Aug.-Sept., fide Atk.

Trametes mollis Fr. On maple. Marquette Co. Sept. 6, fide Pk.

Agaricaceae.

Agaricus haemorrhoidarius Kalchbr. On the ground, at the base of white birch. Marquette Co. Aug. 25, fide C. H. K.

Cantherellus infundibuliformis (Scop.) Fr. Ground. Houghton Co. Aug. 15, fide C. H. K.

Clitocybe amethystina Bolt. Ground, low thickets. Washtenaw Co. June 10, fide C. H. K.

Clitocybe carnosior Pk. On ground, birch woods. Marquette Co. Aug. 28, fide C. H. K.

Clitocybe decora Fr. (Tricholoma multipunctatum Pk.) On rotten wood, hemlock and maple woods. Chippewa Co. July 14, fide C, H. K.

Agaricaceae—Continued.

Clitocybe vilescens Pk. (Gills are whitish, otherwise same). Under spruce. Houghton and Marquette Co. Aug. 5 and 30, fide C. H. K.

Clitopilus conissans Pk. On rotten stumps, hemlock and maple woods. Marquette Co. Sept. 1, fide Pk.

Clitopilus subvilis Pk. Ground, hemlock woods. Houghton Co. July 20, fide C. H. K.

Coprinus lagopides Karst. Low ground, birch woods. Emmet Co. Sept. 20, fide C. H. K.

Collybia abundans Pk. On hemlock log. Marquette Co. Sept. 1. fide C. H. K.

Collybia campanella Pk. (in ed.) On fallen twigs of white cedar. Houghton Co. Aug. 17, fide Pk.

Cortinarius anfractus Fr. Ground, among poplar. Marquette Co. Aug. 27, fide C. H. K.

Cortinarius castaneoides Pk. On moss in swamp. Marquette Co. Aug. 21, fide C. H. K.

Cortinarius communis Pk. Ground, in oak woods. Washtenaw Co. May 28, fide C. H. K.

Cortinarius pulcher Pk. Ground, oak woods. Washtenaw Co. Oct. 9, fide C. H. K.

Cortinarius sulfurinus Quel. Ground, hemlock woods. Emmet Co. Aug. 1905, fide C. H. K.

Cortinarius torvus Fr. Hemlock and balsam woods. Chippewa Co. July 11, fide C. H. K.

Entoloma Peckianum Burt. Ground, maple and birch woods. Marquette Co. Aug. 21, fide Pk.

Galera ovalis Fr. Ground in woods. Houghton Co. July 20, fide C. H. K.

Hygrophorus coccineus (Schaeff.) Fr. Ground, under oak, maple and birch. Marquette Co. Aug. 27, fide C. H. K.

Hygrophorus pallidus Pk. Ground, white birch swamp. Marquette Co. Sept. 4, fide C. H. K.

Hygrophorus parvulus Pk. Ground, maple and birch woods. Marquette Co. Aug. 27, fide C. H. K.

Hygrophorus psittacinus Fr. Ground, low hemlock woods. Houghton Co. Aug. 28, fide C. H. K.

Hygrophorus squamulosus E. & E. Ground, woods. Marquette Co. Aug. 28, fide C. H. K.

Lactarius cinereus Fr. Ground, hemlock swamp. Chippewa Co. July 11.

Lactarius Gerardii Pk. Among spruce and balsam. Chippewa Co. July 14, fide C. H. K.

Lactarius hysginus Fr. Woods. Houghton Co. July 22, fide C. H. K.

Lactarius maculatus Pk. Ground, oak and maple woods. Marquette Co. Aug. 25, fide C. H. K.

Lepiota acerina Pk. On rotten wood, maple woods. Houghton and Alger Co. July 20, etc., fide C. H. K.

Lepiota pulveracea Pk. On rotten hemlock log. Marquette Co. Sept. 2, fide C. H. K.

Marasmius androsaceus (Linn) Fr. On fallen white pine needles. Houghton Co. July, fide Pk.

Agaricaceae—Continued.

Mycena echinipes Lasch. On debris under white cedar. Emmet Co. Sept. 17, fide C. H. K.

Mycena stylobates Pers. On fallen oak leaves. Washtenaw Co. Oct., fide C. H. K.

Omphalia Gerardiana Pk. On Sphagnum. Houghton Co. July 19, fide C. H. K.

Pholiota albocrenulata Pk. Base of living maple. Emmet and Marquette Co. Aug., fide C. H. K.

Pholiota aeruginosa Pk. On R. R. ties and rotten wood in forest. Washtenaw and Houghton Co. July and Sept., fide C. H. K.

Pholiota flammans Fr. Base of yellow birch. Marquette Co. Aug. 29, fide C. H. K.

Pholiota temnophylla Pk. Rotten sticks, etc., low grounds. Houghton Co. July 25, fide C. H. K.

Pholiota squarrosoides Pk. Rotten logs and living trunks of maple. Marquette and Alger Co. Aug., fide C. H. K.

Pleurotus corticatus Fr. On living maple. Marquette Co. Sept. 2, fide C. H. K.

Pleurotus atrocoeruleus griseus Pk. On dead branches of a mountain ash. Marquette Co. Aug. 22, fide Pk.

Pleurotus porrigens albolanatus Pk. On conifer logs. Marquette Co. Sept. 9, fide Pk.

Pluteus flavofuligineus Atk. On rotten logs Houghton Co. July 25, fide C. H. K.

Pluteus umbrosus Pers. Logs, hemlock and maple woods. Houghton Co. Aug. 15, fide C. H. K.

Psathyra elata Mass. (varies slightly in stature and size of spores.) Washtenaw Co. Oct. 6, fide C. H. K.

Psilocybe cernua Fl. Dan. Among grass. Washtenaw Co. May 25, fide C. H. K.

Russula albella Pk. Maple and birch woods. Houghton and Marquette Co. Aug. and Sept., fide C. H. K.

Russula adusta (Pers.) Fr. Marquette Co. Aug., fide C. H. K.

Russula azurea Bres. (Green variety according to Bresadola's figures.) Marquette Co. Sept., fide C. H. K.

Russula brevipes Pk. Birch and maple woods. Houghton Co. July 21, fide C. H. K.

Russula chamaeleontina Fr. White birch swamp. Marquette Co. Aug. 27, fide Pk. (The slightly acrid taste differs from type.)

Russula cyanoxantha (Schaeff.) Fr. Birch, maple and oak woods. Houghton Co. July 31, fide C. H. K.

Russula chloroides Bres. (in sense of Massee.) Birch, maple and oak woods. Houghton Co. July 30, fide C. H. K.

Russula lutea Fr. Houghton Co. July 22, fide C. H. K.

Russula Mariae Pk. (red form.) Sand dune thickets. Marquette Co. Sept. 2, fide Pk.

Russula olivascens Fr. Hemlock and spruce swamp. Chippewa Co. July 11, fide C. H. K.

Russula pectinatoides Pk. (in ed.) Houghton Co. Aug. 3, fide Pk.

Russula puellaris intensior Pk. Maple and birch woods. Houghton Co. Aug. 4, fide C. H. K.

Agaricaceae—Continued.

Russula subdepallens Pk. Oak and maple woods. Houghton Co. Aug. 6, fide C. H. K.

Russula veternosa Fr. Oak woods. Washtenaw Co. July 8, fide Pk.

Stropharia umbonatescens Pk. On dung. Washtenaw Co. Oct. 12, fide C. H. K.

Tricholoma submaculatum Pk. Hemlock woods. Marquette Co. Sept. 8, fide C. H. K.

Tricholoma sulfureum Fr. (with olivaceous tinge.) Maple woods. Houghton Co. July 20, fide C. H. K.

Tricholoma melaleucum Pers. Field and lawns. Washtenaw and Marquette Co. June and Aug., fide C. H. K.

Tricholoma leucocephalum Fr. Hemlock woods. Marquette Co. Sept. 4, fide C. H. K.

University of Michigan.

FLORA OF THE MARQUETTE QUADRANGLE.

Alfred Dachnowski.

Introduction and itinerary.—Two ways are generally recognized today as affording a method of advancing our knowledge of the flora of a state, viz.: The statistical and the experimental physiological. The latter necessitates much time and patient labor for investigations in degree of resistance in plants to prolonged drouth, excessive moisture, light, in variation, adaptation, etc., and the former involves, aside from mere collections of plants, a general study of meteorology, physiography, and soil conditions in their relation to plant life, and a comparison of the statistics of successive periods of time. As a first step the floristic investigation is indispensable; and the important bearing which a collection from the Upper Peninsula would have on problems connected with the general ecological survey and the natural history of Michigan is therefore easily seen. To convey a correct impression of the distribution of plants or animals, or to further at all our knowledge on the question of the specific conditions giving rise to the diversity, it is absolutely essential to obtain lists of collections of the life forms in the different sections of the state. Indeed, a local floral list acquires interest and importance only when compared with lists and habitats of adjacent regions.

One of the earliest attempts in this direction was made by W. A. Burt, who, in 1846, collected in the then primitive region south of Lake Superior, and prepared a catalogue of the plants. As early as 1830–1838, collections of the flora of Upper Michigan were made, and together with those of Mr. F. E. Woods and other collectors of a later date were deposited in the Herbarium of the Botanical Department of the University of Michigan. Perhaps the most extensive collection is that of Mr. Farwell at Keweenaw Point. Casual references to individual and distinct genera have occasionally appeared but as yet no account of the collections as a whole has been published, nor have notes been collected to indicate topographic and general vegetational features. The paper of Whitford (17), and more recently the able work of Mr. Adams (1), and his assistants, and notably that of Dr. C. A. Davis (9) are of special importance in this connection. It is gratifying to know that the additions to statistics hereafter will be made in a manner which shall give us the best results possible, i. e., they will be sufficiently accurate, not only for the needs of the ecologist, but also to the demands of agricultural and industrial interests. For it is needless to emphasize that the collection of statistical and ecological data should be looked upon not as ends but means, not as establishing an expensive precedent, but rather as a temporary device to be managed also in the interests of forest and crop studies.

Through the educational solicitude and the public-spirited generosity of the Hon. Peter White of Marquette, and Mr. Bryant Walker of Detroit, facilities for renewed collections of records and material were made possible, and accordingly, I was directed by Prof. F. C. Newcombe to accompany Dr. C. A. Davis of the State Geological Survey, and to make as thorough a floristic reconnoisance of a northern locality as time and circumstances would permit. Since the headquarters of Dr. Davis was at Marquette, Mich., it was decided to use the Marquette Quadrangle, a topographic map of which has

been published recently by the U. S. Geological Survey, as the area to be studied. It is situated on the south shore of Lake Superior, in a township of the same name, and included between latitude 46° 30′ and 46° 40′ north and longitude 87° 21′ and 87° 30′ west.

The city of Marquette lies on an elevated point between Marquette Bay and Presque Isle harbor. About three miles south of the city is an east and west range of quartzite and granite rocks. Rising rapidly from the lake, it forms Mt. Mesnard in Sec. 34, T. 48 N., R. 25 W. This mountain range is exceptional in its continuity, since broken chains of irregular hills and short ridges of various sizes, separated by swamps, sand areas and lakes is the prevailing character elsewhere. About four miles north of the city occurs a landspur, known as Presque Isle, formed by a protrusion of peculiar rock masses (Dolomite) and with considerable cliffs at the north end.

The region was entered July 9, 1906. After a brief preliminary study it was deemed best to examine the immediate habitat in detail, later to compare it with and include examples of other representative environment of the region, and then to make the work a comparative study of types of habitat. This method involves, of course, as careful a study of the various ecological factors as is usually applied to special problems of field ecology, but lacking time it was thought best to keep in mind a variety of habitats more or less genetically related.

Beginning therefore, with the harbor of Presque Isle, stops of a few days each, were made along the shore of Lake Superior at points consisting of outcropping trap rock, of sandy and gravelly beaches, and of sand dunes. From these points observation and study turned to the bogs and swamps back of the sand dunes and inland, and then to the more elevated sand areas near the city of Marquette, west of Ridge Street. On July 27 the work continued up Mt. Mesnard, including an open ravine, burned areas and clearings, and the more densely forested regions south of Mt. Mesnard. The remaining time was spent in short trips down Dead River, to Partridge and Middle Islands, to Little and Pickerel Lakes, to Escanaba, Wells, Sands, Negaunee and Ishpeming.

Although the collection is far from complete, the specimens collected are nevertheless representative; and the information received from old settlers has proved of value. I wish in this connection to express my sincere appreciation to Hon. Peter White, of Marquette, Mr. Bryant Walker of Detroit, and Prof. F. C. Newcombe for the opportunity afforded me. I am likewise indebted to Dr. Downing of the Marquette State Normal, who has been exceedingly kind, not only in placing at my disposal his collection, but in numerous other ways as well. Special acknowledgment is due to Dr. C. A. Davis, who, in addition to much friendly and helpful suggestion and interest, very generously has given much of his time to the identification of the plants collected.

Topography.—It is unnecessary to describe the geology and topography of this region, as it has been treated repeatedly by others. For this report it is sufficient to point out that the northern and southern halves of the state are readily distinguished. The upper or northern part consists largely of rugged mountains and hilly regions, some of the hills rising 1450 to 1500 feet a. t. (840 to 900 feet above Lake Superior in the vicinity of Marquette), and hence offers a greater complexity in its geological formations and topographical features. The rocks are usually crystalline or metamorphic, except near the lake level, where the Potsdam Sandstone appears. Many strata of the various geological epochs are here represented, in some places

covered deeply by glacial drift. Naturally this gives rise to marked surface characteristics, diversity of topography, and soil and local climatic conditions.

On the other hand, the lower part of the state can be considered as a vast plain of relative uniformity in general features. According to a former State Geologist (Rominger, 13) the Lower Peninsula has been the center point of an oceanic basin, uninterrupted marine deposits following each other in great regularity and representing formations from the early Silurian period on to the end of the Coal (Carboniferous) period. The entire surface of the Lower Peninsula is now covered with glacial drift, in some places to a depth of 800 feet and more. The topographical outlines of today are largely the outcome of the action of moving ice and flowing water, during and following the glacial period, and partly due to the weathering agencies constantly at work modifying these features.

In its extremes the climate of the two peninsulas is somewhat excessive. And yet for some not well-known reason, the edaphic and climatic conditions in the upper part of the state give rise to a vegetation closely related in character to that prevailing in the more southern part of the state, and extremely unlike that to be found around Cheboygan and Presque Isle counties, where the larger areas, at least, are covered with conifers. As in most parts of eastern North America, forests constitute the most extensive and predominating plant formation. Perhaps it is because of the influence of the abundant rainfall, and the very frequent heavy fogs along the lake shore throughout the year—conditions most favorable to tree growth—that Upper Michigan presents the aspect of so richly wooded a country.

FLORA AND DISTRIBUTION.

The flora of the Marquette Quadrangle naturally falls into three groups—that composing the vegetation of rocks and ridges, and that found on sandy soils and in swampy places. By way of introducing some order into the variety of ways in which these groups may be treated, they will be taken up in conformity to the line of survey, under the following heads:

Beach and Promontory.—Beginning at Presque Isle, the beach at the point studied consists of outcropping strata of Potsdam sandstone, tilted about 20°, and farther north of an exposed trap-dike and promontory. Continually exposed to the action of waves during the larger part of the year, and to the action of ice during the latter part of winter, even considerably above the water line the rocks are bare, furnishing neither soil nor a foothold for plants. But beyond the limit reached by waves and ice life can exist. The lichen formation precedes all others, consisting largely of Parmelia conspersa, Lecidea lactea, Stereocaulon coralloides; a few xerophytic mosses gain a foothold, soon forming a slight soil, and evidently representing a brief stage in a succession, which will support still higher forms. In crevices, disintegration permits an accumulation of soil. Several of the hardier plants* like Sibbaldiopsis tridenta, Campanula rotundifolia, Agrostis hyemale, Solidago uliginosa, S. hispida, Opulaster opulifolius, and Bettula papyrifera, are to be found here, and in protected places, even more shade-requiring forms occur, such as Phegopteris dryopteris, Onoclea sensibilis and Dryopteris noveboracensis. Pools, formed by large fissures and by the disintegration of large portions of rock, are quite numerous. The vegetation

* For a more complete list see "Distribution of characteristic plants in the Marquette Region," pp. 98–103.

in the pools consists of algae, and microscopic plant-life. Around the edge occur such northern forms as Carex aurea, Eleocharis palustris glaucescens, Scirpus caespitosus with Pinquicula vulgaris, and Carex viridula, with Primula mistassinica forming tufts, in which the dust and sand carried by the wind is retained, enabling the plants gradually to increase and retain more soil.

Where the rocky beach is still beyond the reach of the unfavorable factors of the environment, and the soil increases in amount and in depth, and is richer in humus, the flora becomes an interesting assembly of forms. However, even without the aid of inorganic processes of weathering, plant societies seem capable of invading and of establishing a soil supporting a tree vegetation. The differences in the habitat are nowhere sharply defined, and hence such plants as those just mentioned are found together with a crevice vegetation of Vaccinium Pennsylvanicum, V. nigrum, Amelanchier Canadensis, Linnæa Americana, Phegopteris phegopteris, and with Fragaria Virginiana, Euthamia graminifolia, young white pine, mountain ash, hemlock, cedar and birch forming a transitional zone leading into the mixed mesophytic forest beyond.

In other places the fluctuations and differences of floral constituents correspond with the changes in the habitat. With a rocky beach retreating inland and becoming steep and precipitous, or broken up into a shingle beach the flora shows no transition zone. The adjacent forest type is directly succeeded by a lichen society.

Dunes.—On the other hand, the formation of a wave deposited terrace below the water-level, and a sandy beach, and the consequent shallowing of the water, is soon followed with a gradual downward movement of the inland vegetation. The sand composing such beach dunes was, no doubt, washed up and worked over by the waves, and later by the winds. In the wave-washed area, the sandy beach is barren of vegetation. Only in places fairly well-protected from winds and shifting sands, a condition is maintained enabling plants to encroach rapidly. In exposed situations, however, the invasion and succession of plants is greatly or entirely retarded. Along Middle and Partridge Bay, west of Presque Isle, are several wind blown sandhills, confined to a narrow belt fringing the lake shore, and presenting quite a contrast to the habitat described above and swamps and bogs back of the dunes. The contour of the dunes, varying from 10 to 15 feet in height, shows that they were shaped by northeast winds. Whatever the origin of these ridges, within them are visible old soil lines, and several scarred trunks of pine trees, long ago buried by the dunes and now again uncovered by wave action.

The life-conditions are exceedingly severe. The intensity of direct summer rays is increased by the low specific heat of the sand, and by reflection. Though slightly below the surface the sand is usually moist, yet the ease with which the surface layers are heated by day and cooled by night gives rise to extreme temperature differences. Nowhere are the winds more severe, dessicating and cutting, and the soil more porous, poorer in nutrient food material, and the evaporation of water so rapid. All of these features combine to furnish conditions excluding almost entirely the possibility of plant life. Nevertheless, at many points a number of plants are able to withstand such conditions. No vegetation is found on the lower or the steep middle beach, but on the upper beach, about 10 feet above the lake level, and sloping gradually into the swamp beyond, the flora is composed of Hudsonia tomentosa, forming clumps of densely tufted growth, as the dominant species, and of the equally efficient dune holders, Vaccinium nigrum, Arcto-

staphylos Uva-ursi, Gaylussaccia resinosa, Vaccinium Pennsylvanicum and Sibbaldiopsis tridentata. Very common tenants, promiscuously scattered, and in this locality of no consequence as soil-binders, are such grasses as Ammophila arenaria, Elymus Canadensis and Cakile edentula. Occasionally found are Amelanchier botryapium, A. rotundifolia, Diervilla diervilla, and now and then Unifolium Canadense, Lathyrus maritimus, Echinochloa Crus-galli, Equisetum arvense, and Rosa Sayi.

The Jack Pine is the most abundant tree, and flourishes best in these xerophytic places. Whitford (17) has suggested that a definite deciduous society is finally developed upon dunes and sandy beaches. It seems as if the mixed forest types further west along the shore, and those on the fossil beaches farther inland were indications of dunes having passed to this stage. Near the Catholic cemetery the undestroyed Norway pines in the young Jack pine forest indicate, perhaps, that this fossil beach had formerly a mixed forest. Changes in water level remaining high or low for a prolonged time (due to periods of greater or less rainfall or changes in drainage) might displace the original flora or give rise to a heterogeneous flora. But whether this suggestion is in accordance with the observed facts is difficult to say. For, in many places where the soil conditions are unfavorable up to a certain limit, the region is certain to have indefinitely a Jack pine aspect. However, it is not the nature of the soil alone which determines that the Jack pine should predominate or be succeeded. The nature of the soil water as determined by the character of the underlying layers, and the ability of this soil to retain water, must be considered as one of the most important of the secondary factors influencing distribution.

Swamps.—The dunes, formerly fixed, have been rejuvenated by the complete removal of mature timber, and are now encroaching more and more inland upon the swamp, partly by actual advance in that direction and the formation of new dunes, partly because of wind and wave action during the storms of autumn. In some places the sand has covered the swamp to a distance of 30 to 40 feet, showing from 6 to 7 wave-action débris lines.

The area of the swamp is extensive, low, not well drained, and caused either by a general sinking of the beach or a raise of water level due to excessive rainfall, evidences of which are clearly seen in the submerged and partly buried trees standing along the lake shore, or perhaps by bars and spits forming across embayments. The silting up of the mouth of Dead River by the wash of the surrounding soil and the accumulation of vegetation may further have hastened the process. This low and wet area is now inhabited by a swamp flora whose zonal arrangement is more or less complete but not always continuous. Since the zonal distribution in swamps is well known the various zones occurring need be mentioned here only briefly.

Starting as ponds or lakes with a multitude of water lilies, bladder-worts, water-milfoil and other pond plants predominating, most swamps are bordered by the bulrushes (Scirpus lacustris, S. subterminalis, S. cyperinus), the swamp cinque-foil (Comarum palustre), Typha latifolia, and others, with sedges like Carex oligosperma, C. Sterilis and C. filiformis encroaching upon the water in the form of a quaking mat. This mat becomes firmer shoreward. Gradually the surface is built up above water level, the decay of these plants preparing the way for another succeeding zone, the Cassandra-Sphagnum vegetation—the true bog flora-comprising cotton-grass (Eriophorum alpinum, E. gracile, E. polystachyon), Andromeda polifolia, Ledum Grœnlandicum, Sarracenia purpurea, Pyrola uliginosa, Drosera rotundifolia, D. intermedia, D. linearis, Oxycoccus oxycoccus, Solidago uliginosa, Dryopteris

thelypteris, Limnorchis dilatata, Lysias orbiculata, Blephariglottis lacera, Myrica Gale, Gyrostachys cernua, Chiogenes hispidula, etc.

As the sedges encroach farther in on the original lake, the movement forward becomes relatively slower, while the filling up increases more rapidly. The zone of the leather-leaved plants gives rise to conditions enabling tamarack or arbor-vitæ, and later spruce, black ash, balsam, white pine and yellow birch to get a foothold. The swamp northeast of the State Normal at Marquette presents this dryer condition. In more open, wet places, the scattered young Norway and Jack pines and hemlock are usually surrounded by a heavy mat of sphagnum, bearing upon it almost an entire Cassandra zone, of course on a small scale. In still dryer places the tamarack and associated balsam-fir, black spruce and black ash has an undergrowth consisting of dwarf dogwood, xerophytic mosses and various members of the huckleberry family.

There are, however, areas where the prevailing bog-societies are not arranged in concentric zones, but parallel. Especially is this the case in areas near the Pioneer Charcoal Blast furnace. The succession is much the same as in lakes and ponds. The sedge zone grades into a Cassandra zone associated with Spiræa salicifolia and alder, which in turn is followed by a tamarack, black spruce and balsam fir society with an undergrowth consisting of a thick carpet of Sphagnum, pitcher plants, snowberry, Labrador tea and others.

With the change of conditions in the environment—largely produced by the plants themselves—a change in the plant societies inevitably follows. The flora is succeeded by a society adapted to the new conditions, which will in time become replaced by other forms. The societies are usually dominated by species which are among the first to invade new areas, thus illustrating the importance of the historical as well as the biological factors. However, these suggestions are far from illustrating concretely the complex agencies involved and the manner in which they are related to produce the particular conditions or environment. The life history of swamps is not always the same, and neither are the factors similar or even easily recognized. Closer observation reveals an extraordinary network of relations that binds every society in its place and endows it with the character it possesses. For a fuller analysis and a more detailed account the reader is referred to the forthcoming paper of Dr. Davis on "The formation, character and distribution of peat bogs in the Northern Peninsula of Michigan" and the literature cited there.

Sand Areas.—On account of the intermediate relation which it bears to the swamps on the one hand, and the rocky hills on the other, the flora of sand-areas will be considered next. Plains of sand, partly terraces and fossil beaches, partly sandy drift, are frequent. The flora is interesting though rather monotonous, and limited both in individuals and species. In the well-marked sand area west of Ridge Street the soil, recently disturbed by man, is a bare sand, in nature like that of the dunes near the lake. In various places portions of the underlying rock crop out like islands. The vegetation consists largely of pioneer plants such as the common weeds and of Hypericum Canadense, Anaphalis margaritacea and Leptilon Canadense; in depressions containing slightly more moisture are found Carex tenuis, C. tribuloides Bebbii, Juncus effusus, J. tenuis, Scirpus cyperinus and Euthamia graminifolia. Near "Sugar Loaf Mountain," northwest of Marquette, and in other places, the sandy plains are covered with a dense growth of Vacciniums yielding a great abundance of fruit. It would be difficult to find

Jack pine of so large size and abundance as in these barrens. Wherever the sandy ridges spread out into wider expansions, as at Sands for instance, forming broad uplands, now denuded of their original tree growth, and not even subjected to cultivation, a Jack pine and xerophytic flora has established itself with Compositæ as its prominent feature. Such plains extend through the metamorphic region to the southern limit of the Upper Peninsula and appear to be indeed the home not only of Jack pine and spruce, but of golden rods, asters, rudbeckias, sweet fern, Pteridium aquilinum, Campanula rotundifolia, Gnaphalium obtusifolium, Commandra umbellata, besides numerous other species.

The pine flora proper is far richer in species, and more interesting. An evergreen arboreal vegetation still forms the most prominent feature of the flora of sand areas and the large number of rocky hills. The societies are dominated by such species as Pinus resinosa, P. strobus, Picea Canadensis, P. mariana, Tsuga Canadensis, Abies balsamea, Juniperus communis and Taxus Canadensis. The undergrowth is not scanty, although in midsummer only traces of the characteristic spring plants are found. The club-mosses flourish here luxuriantly, together with Clintonia borealis, Corallorhiza Corallorhiza, C. multiflora, Linnea Americana, Asplenium filix-foemina, Rubus parviflorus, Phegopteris Dryopteris, Pteridium aquilinum and others. In more open places may be seen Gaultheria procumbens, the bear berry, (Arctostaphylos Uva-ursi) Epigæa repens, Chimaphila umbellata, Fragaria Virginiana, Rosa Sayi, with mosses, liverworts, lichens and fungi in great profusion. In young pine woods are always found white birch (Betula papyrifera), and the poplars (Populus tremuloides, P. grandidentata). Balsam, and especially the yellow birch (Betula lutea), are frequent among them. To what extent the original flora is re-established, or has become mixed or displaced the brief period of investigation failed to show.

Rock Societies.—Originally an unsurpassed tree growth and timber wealth was found here almost uninterrupted. Since no serious obstacles to plant migration from and to all parts are present, it is easily understood why the number of plants endemic to Michigan is small. Completely open on the east and west, naturally the result would be that the plant covering of the state should coincide with the flora of adjoining states. The original arboreal evergreens are now dominated by a society consisting of various maples, Acer nigrum, A. Pennsylvanicum, A. rubrum, A. saccharum, A. spicatum, red oak, elm, basswood, yellow, black and white birch, white and black ash, wild cherry, ninebark, hop-hornbeam, hazel (Corylus rostrata), and dogwood. The beech has not been observed in this locality. It is present, however, south of Marquette, and more numerously, I am told, east of the Au Train River. Deciduous trees predominate wherever a richer and deeper soil covers the heights, the slopes of mountains, and the rocky hills.

The pine is present also, but the changed soil conditions seem to force the pine to give way to the hardwood trees. With the disappearance of the pine, whether through clearing or fire, the deciduous-leaved trees make their appearance, and the undergrowth also becomes more varied.

Nowhere is there a more excellent field of study illustrating the importance of succession than that presented on the rocks of granite and quartzite in the vicinity of Marquette. The tops of several of these ridges are almost as smooth and barren of vegetation as at the day the glaciers left them. Gravity and rain remove any soil formed to lower levels, and the most favorable conditions for plant societies are found, therefore, at the foot of the hill, becoming less favorable higher up the slope. On the rock summits, two conditions

are frequently found to prevail, namely, rock-ridges without much soil, supporting a xerophytic flora, and depressions, with moist and deeper soil supporting either a mesophytic, or, as in some places, a swamp flora.

The succession on rock undoubtedly began with the lichens in an order such as this: First the crustaceous, then the foliaceous lichens, and finally such forms as Cladonia rangiferina, C. pulchella, Stereocaulon paschali, together with Selaginella rupestris and various xerophytic mosses. A large lichen (Umbellicaria), invariably is found covering with its black thalloid frond the bare surfaces, forming a striking feature. Fastened firmly to the rock by holdfasts, it dries up and curls up between rains but remains uninjured until the next shower freshens it up again. Of the ferns frequenting these exposed dry places, the most common are Polypodium vulgare, Phegopteris dryopteris, Woodsia ilvensis, and often also Dryopetris fragrans. The variety of rock vegetation is very noticeable—lichen societies adjoining small depressions containing a miniature swamp flora, or bordering groups of pines, young broadleaved trees, or crevices with a shrubby vegetation. Without the aid of the physical and chemical process of weathering, and in spite of the poverty of the soil, the presence of humus and an abundance of atmospheric moisture enable these plants to succeed. Their existence here, however, is only a very transient one. The quartzite shows almost no disintegration, but with the more or less complete decay of the granite and dolomite, these various societies disappear, having done their share in establishing a soil to support a tree vegetation.

From an ecological point of view, the region has reached a relatively fairly mature stage in various places. Perhaps it is because of marked influences due to the proximity of the great lakes that mixed pine and almost pure deciduous forests are found upon hills and in valleys which would otherwise support only a xerophytic society. That the soil factor is of an equally important influence need not be reiterated. The clay soils of the southern slope of Mount Mesnard with their dense and luxuriant growth of deciduous trees are especially an example of this kind.

The devastating influence of man is not to be disregarded, since by far the greater number of localities studied show unmistakable signs of artificial conditions—clearing, produced both by the cutting and burning of timber. It is needless to describe the dreary and repellent sight which a deserted lumber region of thousands of dead and blackened pines presents. The consequent greater insolation permits only a few plants to thrive in arid, xerophytic conditions like these. Most numerously represented are usually those species found in the immediate neighborhood, which have the lightest seed or a colored fruit, and are rapid growers. Epilobium angustifolium, Erigeron Canadensis, various goldenrods and especially the blackberries spring up everywhere, forming a tangled thicket, giving the clearing the well-known "fire-weed" aspect. A few scattering poplars, white birches and wild red cherries soon appear, overtop the fireweed, gradually shade them out, and maintain themselves until the pines crowd them out, or until the deeper shade conditions enable the maples, basswoods and red oaks to establish themselves.

Rivers and Lakes.—The sections studied near the "Electric Light and Power House"—about four miles northwest of Marquette, and those near Presque Isle, may be considered representative of headwater and of flood-plain conditions of Dead River. At the section first mentioned the stream is shallow, cold and swift-flowing, with a bottom composed of bed rock and gravel. Within the stream there is practically no vegetation. On the banks, however, the pines and deciduous trees of the bordering hills extend down

to the water's edge, and the humus conditions along the margin favor a flora such as that found in the forest. The vegetation that lines the gravelly margin consists principally of large mats of mosses and liverworts; very frequently found are Filix bulbifera, F. fragilis, Equisetum sylvaticum and others.

Nearer Marquette, Dead River is a slow, meandering stream, building up a broad flood plain, and emptying into Presque Isle harbor. The flora in and about the stream is not peculiarly characteristic. Inhabiting the damp margin of the water courses and the borders of low woods are found a shrub society consisting largely of Alder (Alnus incana), associated with several willows, red osier dogwood, and an undergrowth of sensitive and cinnamon ferns, several species of violets, St. John's wort (Hypericum Canadense), Solidago uliginosa, and a number of grasses and sedges pushing out from the mud-flats into the water. Among these are Juncus effusus, Carex tribuloides, Scirpus cyperinus, Carex viridula, C. riparia, C. filiformis, with Dulichium arundinaceum, Calamagrostis Canadensis, and others on the dryer portions. The flora of these flats is at present transitional. The deposition during floods, and the accumulation of plant debris as well as the decreased flow of water since the abandonment of a former extensive mill-dam, raise the level of the mud-flats, the dryer conditions supporting successively a cassandra, alder and willow thicket. But wherever the prevailing conditions are favorable for an increase in sedges and grasses, the river's outlet ceases to exist and a meadow results. This is the case in the areas north along the Southeastern R. R.

The amphibious forms of Dead River grade into distinctly aquatic forms where the slow current gives rise to conditions that usually prevail in ponds and in shallow lakes. The quiet water type consists of Sagittaria, Potomagetons, Myriophyllum, water lilies and others, which toward the shore become more distinctly zonal in arrangement.

The flora of Little, Pickerel and other lakes visited, though characteristic, each in its own way, is so similar to that existing in the river, that further description may be omitted in this preliminary report. On the fine sand of the beach of such lakes, Equisetum hyemale is found along with the usual marginal vegetation, and away from the shore an alder thicket often leads into the pine or deciduous forest. Sometimes the grass and sedge society passes into a cassandra zone, and then into an alder society, the extent of the changes in plant arrangement depending upon various changing conditions in the environment. On rocky shores the coniferous and mixed forests of the slopes come down almost to the margin of the lake, grading at once into an aquatic flora. The pools and crevices that occur on outcropping rocks and on bare rocks in exposed places contain a vegetation very similar to that found in a like environment along the lake shore.

Michigan Military Academy, Orchard Lake, February, 1907.

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TABLE SHOWING IN THE STATIONS DESCRIBED DISTRIBUTION OF CHARACTERISTIC PLANTS IN THE MARQUETTE REGION.

	Promontory.	Beach.	Dunes.	P. I. Swamp.	Swamp in St. X.	West Ridge St.	Sands.	Open Field Ravine.	Mt. Mesnard.	Dead River.	Pickerell Lake.	Little Lake.	Partridge Island.	Escanaba-Wells.	Negaunee.	Ishpeming.
Botrychium Virginianum (L.) Swartz									+							
Osmunda cinnamomea L.									+							
O. Regalis L.					+											
Onoclea sensibilis L.	+									+						
Woodsia Ilvensis (L.) R. Br.							+		+	+			+		+	
W. obtusa (Spreng.) Torr.									+				+			
Filix bulbifera (L.) Underw.									+	+						
F. fragilis (L.) Underw.	+						+	+	+				+		+	+
Polystichum Braunii (Spenner) Fee.											+					
Dryopteris fragrans (L.) Schott																+
D. marginalis (L.) A. Gray.					+				+	+						
D. Noveboracensis (L.) A. Gray.	+									+					+	
D. spinulosa (Retz.) Kuntze.							+		+	+						
D. Thelypteris (L.) A. Gray.					+			+	+	+				+		
Phegopteris Dryopteris (L.) A. Gray.	+						+		+	+						
P. Phegopteris (L.) Underw.	+	+					+		+						+	
Asplenium Filix-fœmina (L.) Bernh							+			+						+
A. Trichomanes L.									+	+					+	
Adiantum pedatum L.	+								+							
Pteridium aquilinum (L.) Kuhn			+		+		+		+							
Polypodium vulgare L.	+						+		+						+	
Equisetum arvense L.			+			+		+	+	+	+					
E. fluviatale L.					+				+							
E. hyemale L.									+	+	+					
E. palustre L.									+							
E. Limosum					+											
E. scirpoides Michx.							+		+							
E. sylvaticum L.											+					
Lycopodium annotinum L.										+						
L. Chamæcyparissus A. B.									+							
L. clavatum L.										+						
L. complanatum L.										+						
L. obscurum dendroideum D. C. Eaton.									+							
Selaginella rupestris (L.) Spreng.									+							
Pinus divaricate (Ait.) Gord.			+	+	+		+									
P. resinosa Ait.			+	+	+		+		+	+				+	+	+
P. strobus L.	+	+		+	+		+		+	+				+	+	+
Larix laricina (Du Roi) Koch				+	+											
Picea Canadensis (Mill.) B. S. P.									+	+						
P. Mariana (Mill.) B. S. P.					+		+			+						
Tsuga Canadensis (L.) Carriere	+				+		+		+							
Abies balsamea (L.) Miller.							+			+						
Thuja occidentalis L.	+						+		+							
Juniperus communis L.							+		+							
J. nana Willd.					+											
J. Sabina L.							+									
Taxus Canadensis Marsh.							+		+							
Typha latifolia L.				+	+											
Sparganium minimum Fries										+						
S. simplex Hudson										+						
S. simplex angustifolium (Michx.) Engelm				+					+			+				
Potamogeton diversifolius Raf											+					
P. heterophyllus Schreb.				+						+						
P. lucens L.											+					
P. natans L.									+	+						
P. pauciflorus Pursh.																+
P. perfoliatus L.											+					
P. Robinsii Oakes												+				
Naias flexilis (Willd.) Rost. & Schmidt.												+				
Scheuchzeria palustris L.				+												
Sagittaria latifolia Willd.				+					+	+						
E. ramosus (Walt.) B. S. P.								+		+						
Leptilon Canadense (L.) Britton.						+		+		+						
Doellingeria umbellata (Mill.) Nees.									+							
Antennaria neodioica Greene.									+						+	
Anaphalis margaritacea (L.) Benth. & Hook.				+		+		+								
Gnaphalium obtusifolium L.							+									

DISTRIBUTION OF CHARACTERISTIC PLANTS.—CONTINUED.

	Promontory.	Beach.	Dunes.	P. L. Swamp.	Swamp in St. N.	West Ridge St.	Sands.	Open Field Ravine.	Mt. Mesnard.	Dead River.	Pickerell Lake.	Little Lake.	Partridge Island.	Escanaba-Wells.	Negaunee.	Ishpeming.
Adenocaulon bicolor Hook.									+							
Heliopsis scabra Dunal.									+							
Rudbeckia hirta L.							+		+			+				
Achillea Millefolium L.		+														
Chrysanthemum Leucanthemum L.					+			+	+							
Tanacetum vulgare L.										+						
Carduus muticus (Mich.) Pers.									+							
Philotria Canadensis, (Michx.) Britton											+					
Sorghastrum avenaceum (Michx.) Nash				+												
Echinochloa Crus-galli (L.) Beauv.			+													
Panicum Scribnerianum Nash.													+			
Cenchrus tribuloides L.														+		
Muhlenbergia sylvatica Torr.									+							
Phleum pratense L.		+			+				+							
Cinna latifolia (Trev.) Griseb.									+	+						
Agrostis alba L.					+	+			+							
A. hyemalis (Walt.) B. S. P.	+				+	+				+	+			+		+
Calamagrostis Canadensis (Michx.) Beauv.				+	+					+						
Ammophila arenaria (L.) Link			+													
Calamovilfa longifolia (Hook.) Hack.		+														
Deschampsia flexuosa (L.) Trin.	+			+					+							
Danthonia spicata (L.) Beauv.					+											
Poa compressa L.				+		+			+							
P. debilis Torr.									+		+					
P. flava L.		+			+	+	+		+	+						
P. pratensis L.		+			+					+						
P. trivialis L.						+										
Panicularia Americana (Torr.) MacM.					+					+						+
P. Canadensis (Michx.) Kuntze									+			+				
P. pallida (Torr.) Kuntze									+	+						
Festuca octoflora Walt.			+													
F. ovina L.		+														
Bromus asper Murr.										+						
B. ciliatus L.						+										
B. Kalmii A. Gray.														+		
Agropyron caninum (L.) R. & S.		+	+			+										
A. repens (L.) Beauv.						+										
Hordeum jubatum L.									+							
Elymus Canadensis L.			+						+							
E. Virginicus L.										+						
Dulichium arundinaceum (L.) Britt.										+		+				
Eleocharis ovata (Roth.) R. & S.															+	
E. palustris (L.) R. & S.				+							+					
E. palustris glaucescens (Willd.) A. Gray	+								+							
E. tenuis (Willd.) Schultes										+						
Scirpus atrovirens Muhl.								+						+		
S. caespitosus L.	+															
S. cyperinus (L.) Kunth.				+		+				+						
S. lacustris L.				+							+					
S. lineatus Michx.				+												
S. subterminalis Torr.				+							+					
S. sylvaticus L.				+												
Eriophorum alpinum L.					+											
E. gracile Koch.				+	+											
E. polystachyon L.				+												
E. Virginicum L.																+
Rhynchospora alba (L.) Vahl.				+	+											
R. capillacea Torr.				+												
Cladium mariscoides Torr.												+				
Carex albolutescens cumulata Bailey.				+												
C. aquatilis Wahl.				+												
C. arctata Boott.									+							
C. aurea Nutt.	+															
C. brunnescens (Pers.) Poir.	+															
C. crinita Lam.									+	+						
C. Deweyana Schwein.									+		+					
C. filiformis L.				+						+		+				
C. flava L.									+							
C. fusca All.	+															
C. interior Bailey.				+												
C. intumescens Rudge.										+	+					
C. lanuginosa Michx.					+											
C. limosa L.				+												

DISTRIBUTION OF CHARACTERISTIC PLANTS.—CONTINUED.

	Promontory.	Beach.	Dunes.	P. I. Swamp.	Swamp in St. N.	West Ridge St.	Sands.	Open Field Ravine.	Mt. Mesnard.	Dead River.	Pickerell Lake.	Little Lake.	Partridge Island.	Escanaba-Wells.	Negaunee.	Ishpeming.
C. oligosperma Michx.				+								+				
C. Pseudo-Cyperus L										+						
C. retrorsa Schwein.							+			+						
C. rosea Schk.					+											
C. scabrata Schwein.											+					
C. scoparia Schk.					+			+								
C. siccata Dewey											+					
C. sterilis Willd.				+	+											
C. sterilis cephalantha Bailey				+	+											
C. straminea Willd.									+							
C. stricta Lam.				+												
C. tenella Schk.				+												
C. tenuis Rudge						+										
C. teretiuscula Good.				+												
C. tribuloides Wahl.				+						+				+		
C. tribuloides Bebii Bailey				+		+			+							
C. tribuloides moniliformis (Tuck.) Britton				+												
C. Tuckermanii Dewey										+						
C. utriculata Boott									+		+					
C. viridula Michx.	+			+						+						
C. vulpinoidea Michx.								+		+						
Arisæma triphyllum (L.) Torr.															+	
Calla palustris L.																+
Eriocaulon septangulare With.												+				
Juncus Balticus littoralis Engelm.				+												
Juncus bufonius L.				+												+
J. Canadensis J. Gay				+	+		+	+	+							+
J. effusus L.				+		+		+	+	+						
J. nodosus L.								+	+							
J. tenuis Willd				+		+		+								
Zygadenus elegans Pursh.			+													
Clintonia borealis (Ait.) Raf.							+			+						
Unifolium Canadense (Desf.) Greene			+				+			+						
Streptopus amplexifolius (L.) DC.										+						
Salomonia biflora (Walt.) Britt.									+							
Trillium cernuum L									+							
Gymnandeniopsis clavelatta (Michx.) Rydb.											+					
Limnorchis dilatata (Pursh.) Rydb.					+											
L. hyperborea (L.) Rydb									+							
Lysias orbiculata (Pursh.) Rydb.					+						+					
Habenaria tridentata					+				+			+	+			
Blephariglottis lacera (Michx.) Rydb.					+											
B. psycodes (L.) Rydb.										+	+					
Pogonia ophioglossoides (L.) Ker.				+												
Limodorum tuberosum L.				+												
Gyrostachys cernua (L.) Kuntze.					+				+		+					
G. gracilis (Bigel.) Kuntze									+							
Corallorhiza Corallorhiza (L.) Karst							+			+						
C. multiflora Nutt.							+		+	+	+					
C. odontorhiza (Willd.) Nutt							+		+	+						
Myrica Gale L.				+	+		+		+							
Comptonia peregrina (L.) Coulter					+											
Populus balsaminifera L.															+	
P. deltoides Marsh.										+						
P. grandidentata Michx.							+			+					+	
P. tremuloides Michx.					+		+									
Salix candida Fluegge.														+		
S. glaucophylla Bebb.					+											
S. humilis Marshall									+	+		+				
S. myrtilloides L.			+	+	+				+							
Ostrya Virginica (Mill.) Willd.									+							
Corylus rostrata Ait.									+	+						
Betula lutea Michx.							+		+							
B. papyrifera Marshall.	+						+		+	+						
Alnus incana (L.) Willd.				+	+											
Quercus coccinea Wang.												+				
Q. rubra L.									+					+		
Humulus lupulus L.															+	
Comandra umbellata (L.) Nutt.			+				+		+	+						
Rumex acetosella L.		+				+		+		+						+
Polygonum amphibium L.											+					

DISTRIBUTION OF CHARACTERISTIC PLANTS.—CONTINUED.

	Promontory.	Beach.	Dunes.	P. I. Swamp.	Swamp in St. N.	West Ridge St.	Sands.	Open Field Ravine.	Mt. Mesnard.	Dead River.	Pickerell Lake.	Little Lake.	Partridge Island.	Escanaba-Wells.	Negaunee.	Ishpeming.
P. cilinode Michx.									+							
P. Hydropiper L.														+		
P. hydropiperoides Michx.									+							
P. sagittatum L.									+	+						
P. scandens L.									+							
Polygonella articulata (L.) Meism		+	+						+							
Chenopodium album L.									+							
C. Botrys L														+		
C. hybridum L									+							
Blitum capitatum L.														+		
Cycloloma atriplicifolium (Spreng.) Coulter														+		
Corispermum hyssopifolium L.		+														
Salsola Tragus L.														+		
Amaranthus græcizans L.														+		
Mollugo verticillata L.												+				
Silene noctiflora L.							+									
Cerastium vulgatum L.														+		
Coptis trifolia (L.) Salisb.									+							
Actæa alba (L.) Mill.									+							
Aquilegia Canadensis L.										+					+	
Ranunculus acris L						+		+	+							
R. sceleratus L.																+
Batrachium trichophyllum (Chaix.) Bossch.									+							
Thalictrum purpurascens L										+						
Capnoides sempervirens (L.) Borek.									+							
Lepidium Virginicum L						+			+							
Thlaspi arvense L.									+							
Sisymbrium altissimum L.									+							
Cakile edentula (Bigel.) Hook.			+													
Roripa hispida (Desv.) Britton.										+						
R. palustris (L.) Bess.									+	+						
Cardamine flexuosa With.									+							
Bursa Bursa-pastoris (L.) Britton									+							
Sarracenia purpurea L				+	+											
Drosera intermedia Hayne.				+												
D. linearis Goldie.				+												
D. longifolia L.				+												
D. rotundifolia L.				+	+					+						
Mitella nuda L.							+		+							
Ribes lactustre (Pers.) Poir															+	
Opulaster opulifolius (L.) Kuntze.	+															
Spiræa salicifolia L.				+	+				+	+						
Rubus Americanus (Pers.) O. A. F.									+							
R. Canadensis L.					+											
R. parviflorus Nutt.							+		+	+						
R. strigosus Michx.															+	
Drymocallis arguta (Pursh.) Rydb.									+						+	
Sibbaldiopsis tridentata (Soland.) Rydb	+		+						+							
Fragaria Americana (Porter.) Britton.																
F. Virginiana Duchesne	+	+					+		+							
Comarum palustre (L.) Marsh.				+												+
Potentilla argentea L.						+			+							
P. Monspeliensis L.									+							
Geum macrophyllum Willd.														+		
G. strictum Aiton.									+							
Agrimonia parviflora Soland.															+	
Rosa Carolina L.					+											
R. Engelmanni S. Wats.										+						
R. Sayi Schwein.	+		+													
Sorbus Americana Marsh	+								+							
Aronia nigra (Willd.) Britton.					+											
Amelanchier alnifolia Nutt.		+		+					+							
A. Canadensis (L.) Medic.	+	+											+			
A. Botryapium (L. F.) DC.			+													
A. rotundifolia (Michx.) Roem.			+										+			
Cratægus macrantha Lodd.			+				+									
Prunus Pennsylvanica L.										+						
Prunus pumila L.		+	+						+							
P. Virginiana L.										+						
Trifolium aureum Poll.									+							
T. repens L.						+										

DISTRIBUTION OF CHARACTERISTIC PLANTS.—Continued.

	Promontory.	Beach.	Dunes.	P. I. Swamp.	Swamp in St. N	West Ridge St.	Sands.	Open Field Ravine.	Mt. Mesnard.	Dead River.	Pickerell Lake.	Little Lake.	Partridge Island.	Escoral a Wells.	Negaunee.	Ishpeming.
Lathyrus maritimus (L.) Bigel.			+													
Oxalis Acetosella L.							+		+							
Linum usitatissimum L.							+		+							
Euphorbia Cyparissias L.								+								
E. Helioscopia L.									+							
Callitriche bifida (L.) Morong.							+		+	+						
Rhus glabra L.										+						
Ilex verticillata (L.) A. Gray.					+				+	+						
Acer nigrum Michx.									+							
A. Pennsylvanicum L.									+							
A. rubrum L.			+						+	+						
A. Saccharum Marsh.									+	+						
A. spicatum Lam.									+							
Impatiens biflora Walt.										+						
Tilia Americana L.									+	+					+	
Abutilon Abutilon (L.) Rusby.								+								
Hypericum Candense L.						+		+		+						
H. ellipticum Hook.									+							
H. mutilum L.							+					+				
H. perforatum L.									+							
Triadenum Virginicum (L.) Raf.					+											
Helianthemum Canadense (L.) Michx.		+	+						+							
Hudsonia tomentosa Nutt.			+													
Viola Labradorica Schrank.									+				+			
V. pubescens Aiton.									+							
V. renifolia A. Gray.					+					+						
Lepargyraea Canadensis (L.) Green.									+							
Chamaenerion angustifolium (L.) Scop.				+					+							
Epilobium adenocaulon Haussk.				+				+		+				+		+
E. lineare Muhl.				+	+											+
Onagra biennis (L.) Scop.		+						+	+							
Kneiffia pumila (L.) Spach.									+							
Circaea alpina L.									+		+					
Myriophyllum heterophyllum Michx.				+					+	+	+					
M. spicatum L.											+					
Aralia hispida Vent.				+			+					+				
A. nudicaulis L.										+						
Sium cicutaefolium Gmel.									+	+						
Cicuta bulbifera L.																+
Deringa Canadensis (L.) Kuntze.									+							
Cornus Canadensis L.			+		+				+	+		+				
C. circinata L. Her.									+							
C. stolonifera Michx.			+	+	+											
Pyrola elliptica Nutt.									+	+						
P. secunda L.							+		+	+						
P. uliginosa Torr.					+											
Chimaphila umbellata (L.) Nutt.							+				+					
Monotropa uniflora L.																
Hypopitys Hypopitys (L.) Small.									+							
Ledum Groenlandicum OEder.				+	+											+
Kalmia glauca Ait.					+											+
Andromeda Polifolia L.				+	+											
Chamaedaphne Calyculata (L.) Moench.				+	+											+
Epigaea repens L.					+		+		+	+						
Gaultheria procumbens L.					+		+		+	+						
Arctostaphylos Uva-Ursi (L.) Spreng.			+				+		+							
Gaylussacia resinosa (Ait.) Torr.			+				+		+							
Vaccinium membranaceum Dougl.											+					
V. nigrum (Wood) Britton.	+		+										+			
V. Pennsylvanicum Lam.	+		+										+			
Chiogenes hispidula (L.) T. & G.				+			+		+	+						
Oxycoccus Oxycoccus (L.) MacM.				+	+											+
Primula Mistassinica Michx.	+															
Lysimachia terrestris (L.) B. S. P.					+					+						+
Trientalis Americana (Pers.) Pursh.							+									
Gentina Andrewsii Griesb.									+					+		
Tetragonanthus deflexus (J. E. Smith) Kuntze.										+						
Menyanthes trifoliata L.				+												
Apocynum androsaemifolium L.									+							
Convolvulus spithamaeus L.									+							
Lappula Lappula (L.) Karst.									+							
Lithospermum officinala L.									+							

DISTRIBUTION OF CHARACTERISTIC PLANTS.—Concluded.

	Promontory.	Beach.	Dunes.	P. I. Swamp.	Swamp in St. N.	West Ridge St.	Sands.	Open Field Ravine.	Mt. Mesnard.	Dead River.	Pickerell Lake.	Little Lake.	Partridge Island.	Escanaba-Wells.	Negaunee.	Ishpeming.
Verbena hastata L														+		
Scutellaria galericulata L										+						
S. lateriflora L										+						
Prunella vulgaris L								+	+	+						
Leonurus Cardiaca L									+							
Clinopodium vulgare L							+	+	+							
Lycopus Americanus Muhl									+							
L. rubellus Mœnch										+						
Mentha Canadensis L									+							
Solanum nigrum L														+		
Chelone glabra L								+	+			+				
Veronica Americana Schwein										+	+					
Melampyrum lineare Lam					+		+			+						+
Utricularia cornuta Michx				+												
U. intermedia Hayne				+								+				
U. minor L									+							
Pinguicula vulgaris L	+															
Plantago major L															+	
Houstonia longifolia Gaertn															+	
Galium asprellum Michx										+						
G. triflorum Michx									+							
G. trifidum L	+															
Sambucus Canadensis L									+	+						
Linnæa Americana Forbes	+	+			+		+		+	+						
Symphoricarpos pauciflorus (Robbins) Britton									+							
Diervilla Diervilla (L.) MacM.			+							+						
Campanula Americana L.								+								
C. aparinoides Pursh									+					+		
C. rotundifolia L	+						+		+			+				
C. rapunculoides L								+	+							
Lobelia inflata L								+	+							
Adopogon Virginicum (L.) Kuntze							+					+				
Taraxacum Taraxacum (L.) Karst										+						
Lactuca Canadensis L									+					+		
Hieracium Canadense Michx										+		+		+		
H. Gronovii L								+	+							
H. paniculatum L										+						
H. scabrum Michx							+		+							
Nabalus albus (L.) Hook									+							
N. altissimus (L.) Hook										+						
Eupatorium perfoliatum L														+		
Grindelia squarrosa (Pursh.) Dunal										+						
Solidago cæsia L										+						
S. Canadensis L							+		+			+		+		
S. hispida Muhl	+						+		+			+		+		
S. juncea Ait	+						+	+				+				
S. nemoralis Ait							+		+			+		+		
S. Purshii T. C. Porter									+				+			
S. rugosa Mill														+		
S. serotina Ait									+							
S. uliginosa Nutt	+			+	+				+			+			+	
S. Virgaurea Gillmani (A. Gray) T. C. Porter				+												
Euthamia graminifolia (L.) Nutt	+	+			+	+			+	+		+				
Aster lævis L							+		+			+			+	
A. macrophyllus L							+		+	+						
A. puniceus L					+							+				
A. sagittifolius Willd															+	
A. Tradescanti L								+	+	+						
A. undulatus L							+		+							
Erigeron annuus (L.) Pers					+											

THE FLORA OF SOUTHWESTERN MICHIGAN.

H. S. Pepoon.

In dealing with our subject understandingly it will be necessary to have a reasonably thorough knowledge of the physical peculiarites of the region under consideration, including the facts of topography, soil, water supply, surface drainage, agricultural activities and more or less behind and influencing all, the climatic phenomena.

The district that has been thoroughly investigated during the last five years embraces a portion of the counties of Berrien, Cass and Van Buren, covering an area of nearly 60 square miles and occupying a strip of country 10 miles by 6, besides including a number of trips to outlying portions of the three counties named. The latter covering more particularly the region between Keeler and Lake Michigan. A reference to the map will show at a glance the position occupied by the explored area with reference to the adjacent parts of the state.

The topography is determined by the fact that the whole of this part of Michigan is a drift region, lying somewhat west of the terminal morraine of the Michigan lobe, which skirts the present shore line of Lake Michigan at a distance of 20 miles or more. The general surface is fairly level, but broken in many places by the low-lying areas of former drainage, and with very numerous and deep depressions of very diverse magnitude. The smaller of these are commonly circular in outline, 20 or more rods across and 30 to 40 feet deep, often having a small marsh at the bottom. Those of larger size are more irregular and contain shallow ponds fringed with thickets.

Besides these depressions, however, there are numerous much larger ones, the lower levels occupied with lakes of many acres extent or even in one or two cases covering more than a square mile. These lakes are a very characteristic feature, and seem to answer in every detail those described in The Lakes of Southeastern Wisconsin as having been formed by the lodgment of large ice-masses and their subsequent slow meeting. (See above work, page —.)

In the order of their size we find Lakes Magician, Crooked, Dewey, Round, Pipestone, Cable, Keeler, Brown, Jarvis, besides a number more for the names of which reference is made to the map. A very peculiar fact connected with the lakes is that all except Magician and possibly the Pipestone lake have sloping sandy or gravelly shores, whereas the former has no beach at all, but an abrupt shore line. This lake also is the only one except Pipestone with a natural outlet.

The drainage is very poor, there being only two natural water courses in the district, namely, Dowagiac Creek and its affluent, Silver Creek, which latter drains Lake Magician, and Pipestone Creek, the outlet of the lake of that name. These streams send their waters eventually into Lake Michigan through the St. Joe river. A number of drainage ditches have been dug along the lines of lost drainage before mentioned, emptying at length into the streams named. The surface of the land adjacent to these outlets is very flat and low lying, and in the case of Dowagiac Creek forming the very extensive and noted Dowagiac Swamp. In the extreme northwest part

of the district are one or two small cold trout brooks that empty their waters into the Paw Paw river.

Starting east of Keeler center and running north of east, is a sand ridge that in some places almost partakes of the character of a dune. In the northwestern part of the region under consideration is found a series of quite precipitous bluffy slopes that border low land to the west. This hill region is remarkable in many ways and will be referred to very often in the following pages.

Another feature of topography is the presence of very extensive marshes covering much of the northeast and east part, and but little depressed below the surrounding lands. These have largely been imperfectly drained by ditches leading to the Dowagiac Creek. They seem to be, in fact, upper levels of that creek swamp, and seem to locate the upper stage of a former extensive lake that filled the whole of the Dowagiac Creek region with an outlet to the southwest. The soil is, throughout the higher lands, a gravelly or sandy loam with some admixture of clay, the latter predominating as a subsoil in the rougher northwest and west portions. The soil of the flat lands and marsh areas is very black from humus and has a large per cent of decomposed sphagnum in its constitution. A number of strips are so sandy as to become practically sterile and useless for agriculture, and so are given over to natural growths. Marl is found in large amount in the lakes as a bottom product, probably of plant origin.

From an agricultural and horticultural stand-point the soil is not strong, but with clover or fertilizers, well adapted to general crops, particularly beans, and eminently fitted for the growth of small fruits, vineyards and orchards Probably not much more than 50 per cent is thus utilized, the balance being marsh, forest or waste, or occupied by water bodies.

Climatically the district enjoys a fairly equable temperature, the range being from about zero in winter to 90 in summer. Rain and snow are well distributed through the months, although August is very apt to be dry. The average rainfall is — inches, and the average temperature —. The prevailing summer winds are southwesterly and westerly, but with many shifts to east. In this connection it is well to record the remarkable climatic phenomena of Oct. 10–11, 1906. Oct. 10 was a warm day, but cooler by dark, and the late retiring citizen noted a commencing snow fall. The vegetation was in full green leaf. The morning of the 11th dawned with from 8 to 12 inches of snow and a temperature of 2–6 above zero. Forests were broken down by the snow, and peaches were apparently killed root and branch.

The district may be readily divided into the following more or less well defined plant associations, each of which will be considered in detail: 1st. The wooded Dowagiac swamp with its connected spurs extending up the small or large creeks and ditches joining Dowagiac Creek. 2. The grassy or open bog. 3. The tamarack and huckleberry marsh. 4. The ponds and lakes with the larger Silver Creek. 5. The upland oak and hickory lands. 6. The beech and maple lands. 7. The isolated pine barrens. 8. The gravelly lake shores. 9. The wooded bluffs bordering some of the lakes.

I. The Dowagiac swamp is covered with a very heavy growth of Ulmus Americana, Acer saccharinum, Traxinus nigra and Americana, Betula lenta and nigra, Quercus palustris and platanoides, with isolated groves of Pinus strobus, Thuja Platanus and Nyssa. The denser growth has but little undergrowth, but in more open and sunny places are many plants peculiar to this region. Among the more noteworthy may be named, Botrychium dissectum,

growing in most intimate association with B. Virginicum, and behaving in all particulars like a mere form of the latter. Allium tricoccum fairly whitens the ground during August when it is in full bloom; Habenaria psycodes is very common. In marshy spots Saururus grows abundantly. Alnus incana is limited to a few localities. Boehmeria is, with Urticastrum, a complete forest carpet. The latter, in partnership with the innumerable mosquitoes, and aggravated by the constant fear of Massasaugas that here abound, makes botanizing in these dark shades by no means pleasant. Polygonum Virginianum abounds. Isopyrum and actæa rubra are fond on rich knolls, the latter nowhere else in the whole area explored. Caulophyllum is very abundant, growing in large patches. Benzoin is conspicuous, especially in early spring, when its yellow bloom fairly covers the twigs and again when the bright scarlet fruit is ripe in September. Polygala paucifolia is found in one isolated area in a Thuja swamp. Rhus radicans with Parthenocissus grow to a size I have never before seen, and practically every trunk is a living column of green by reason of their growth. Impatiens aurea grows 6 feet high in perfect jungles, occasionally giving place to I. biflora which vies with the former in size. Aralia racemosa grows to a great size, and contrasts strongly with its tiny relative, Panax trifolium, that whitens small portions of the ground with its tiny flower clusters. Conioselinum is a very rare pant, and has not yet been seen in bloom. In the aforesaid Thuja swamp cornus Canadensis flourishes, always on prostrate logs, with the two Mitellas. Lobelia cardinalis is abundant locally and brightens wonderfully the dismal shades.

Leaving these somber regions we come to one almost opposite in every particular. The open bogs are found here and there, mostly bordering the wooded swamp, and almost invariably with a cold spring rivulet encircling or cutting them. Some examples of very local plant distribution are found. A number of gramineae are to be found, the rarest being Zizania. Among the sedges Eleocharis rostellata or "trip-grass" is a very aberrant form of that genus, and covers densely large portions of the bog, but so inconspicuous is it that it is often unnoticed. Tofieldia and Zygadenus elegans are frequent. An interesting bit of ecological botany is suggested here by the fact that in northwestern Illinois the latter plant grows habitually on the wet limestone cliffs. Allium cernuum, "on banks and hillsides" the books say, fairly tints the grass in places. And this leads me to say that much remains *unsaid* about the habitats of many of our plants. For example Cypripedium reginæ grows only in these cold bogs, along with Limodorum, but in Jo Daviess Co., Ill., both species are only found on damp shaded cliff brows that face the north. It is very certain the soils are unlike, the topography could not be more different, and the only element of similarity is the constant unfailing moisture, which leads me to suspect that these orchids are also very largely "air plants." Pogonia ophioglossoides is common, and so, also, is Blephariglottis lacera. Here Salix candida and Smyotilloides thrive, and Caltha, of course, makes golden the spot in early spring. The Droseras, rotundifolia and intermedia are noted, the latter actually tinting the surface with its red coloration, so abundant is it. Sarracenia is locally common, but many seemingly suitable spots are vacant. Parnassia in August, Saxifraga Pennsylvanica in June, are much in evidence and Geum strictum and rivale are among the noteworthy plants of summer. The latter is very rare and local. The genuine Viola cucullata is common and entirely distinct from the forms that formerly paraded under that name, but now bear others, as V. papilionacea. Among the umbellifera are two

or three worthy of notice. Hydrocolyle umbellata shares with the tiny Selaginella apus in carpeting the damp surface. Along the cold brooks a powerfully scented species, Bevula erecta, grows in mats and fringes. Of the odor nothing is said in the books. Its small flowers remind of caraway. Gentiana crinita is an occasional plant, but the soil of these bogs does not cause the unlimited numbers seen in the wet sandy depressions of Lake county, Ind. Mimulus ringens is a pretty plant when left to its boggy haunts, but a failure as a bouquet flower. Lobelia kalmii dots the green with its small blue eyes, and adds greatly to the charm of the place. Nabulus racemosus and Lacinaria spicata complete the list.

The tamarack and blueberry marshes are almost invariably one and the same, the proportions of the two species varying from practical sole occupancy to a half and half arrangement. These swamps are very common, and afford no small revenue to the owners in berries and telephone poles. The flora is not large because of the dense growth of the dominant species, but a few varieties only are found here. Sphagnum is always abundant, and in itself keeps down much plant growth.

The Vacciniums are three, or possibly four, those furnishing the bulk of the berries being V. corymbosum and V. atrococcum, the latter very distinct, and strange it is that it was so long overlooked. A white form of corymbosum is occasional and of superior quality. Certain other shrubs are certain to appear in admixture. Aronia nigra simulates in leaf Vaccinium so well that one looks twice to be sure. Ilteoides is occasional and very neat and pretty, especially in fruit. Prunus Pennsylvanica is frequent but not really at home. Smilax hispida occurs only in such places and is excessively rare. Certain willows are common and one, Salix serissima, was long overlooked as simply S. lucida, but the two are strikingly distinct. S. Bebbiana is ever present, but not peculiar to these swamps, for its favorite haunts are shores and wet lands generally.

Among herbaceous forms Woodwardia is common and striking and grows associated with a shrub overlooked in the above list but very abundant, forming such dense mats that passage except over the tops is almost prohibited. This shrub is Chamædaphne, and in April is a pretty sight with its wealth of white racemes. Growing with it and commonly overlooked, is Andromeda polifolia, a very much more rare form. Cypripedium acaule is found, and always associated with the scattered pines found in these marshes. This association holds good also in Indiana where this species has been found by the writer. The paucity of herbs is thus strikingly shown, for the above practically exhausts the list.

There is another form of marsh found intermixed with the above, but strikingly different, and seemingly because its drainage is more perfect. Sphagnum giving place to Fontanalis and other water loving mosses, and the vegetation being much more of a mixture. While an occasional Vaccinium is observed, the shrubs are generally willows, Spirea salicifolia, rosa carolina, with here and there knolls supporting Populus tremuloides and Rhus vernix. The herbs are a heterogeneous mass of Polygonums, P. sagittatum, P. hydropiperoides, P. emersum, Rumex Brittanica, with here and there Asplenium thelypteris, great clumps of Osmunda cinnamomea and various swamp asters, the whole forming a most trying obstacle to smooth and easy pedestrianism.

On the borders of these marshes are found a number of peculiar species. The soil is rich, black and moist with much shade given by elms, poplars and swamp white oaks and black gums. Here an occasional Cypripedium

hirsutum is seen. The exceedingly rare Cœoglossum tracteatum has been found *twice*. Blephanglottis ciliaris *once*. B. psycodes is common. Corallorhiza corallorhiza and C. odontorhiza may be found by patient search. Mœhringia, Thalictrum purpurascens, Cardamine purpura, Rubus Americanus and R. hispidus and Agrimonia parriflora, all these will be found. The latter is equally at home on barren and dry hillsides, where, if anything, it is even more vigorous. Another interesting plant is Polygala viridescens, found in *one* such habitat. Solidago rugosa, Helianthus giganteus and Carduus muticus will suffice to finish this enumeration.

The plants of the lakes, ponds and stagnant streams may be considered as a single association, although each body of water has one or more peculiar features. All of these waters have many Potomogetons, the most striking, P. praelongus growing often in 12 feet and forming miniature sub lacustrine forests, haunts of sunfish and the bane of the troller. Scirpus validus covers a very large area of Magician, its outer margin almost exactly marking the fathom line. S. Americanus forms a zone in one foot of water and makes a very dense growth, difficult to penetrate with a boat. Two other plants forms isolated patches in Lake Magician. Eleocharis interstincta covers nearly an acre near the outlet, and Juncus sp. makes dense mats in the shoals of the southeast shore. Naias hexilis is very abundant in most of the lakes, forming beautiful tufts in shoal water, but becoming much elongated in deep water, where it is found to a depth of 15 feet. N. gracillina is common in Crooked Lake and is very unlike its more vigorous relative. It may be in place here to note the immense growth of Chara in the deep waters of Magician, having been found at as great a depth as 30 feet. It seems to be the marl producer, as this lake has a marl bottom, and entirely different, therefore, from all the others in the district.

In Cable Lake is a deep water growth of Isoetes echinospora Brauni that may be gathered in large quantities after storms. I have not been able to find this plant in situ, and have a theory that it may be dislodged from the deep by the blue-gills, so very abundant in this lake. This place is the home of the finest strain of Castalia odorata I have ever seen, the richness of the leaf coloration being very remarkable, actually becoming a clear, deep, uniform red, totally unlike the mere tinting found in Magician forms. Immense numbers of Eriocaulon septangulare grow from the shoals of both Cable and Dewey well up onto the beach. In both, also, in one or two inches of water grow three Utricularas, U. gibba, U. resupinata and U. corunta, the resupinata occurring by the thousand and forming a distinct band of growth. In Silver Creek, the Magician outlet, are found two more of this genus, U. vulgaris and U. biflora, the latter occupying a small area about 10 x 30 feet.

Returning a little, Castalia tuberosa grows by myriads in this same stream, and Brasenia is common. Here again a very striking difference occurs between this stream form and that found in Round Lake, where the leaves are fully twice the size and richly colored red below, and with enough mucilage on their lower surface for a dram vial. Equisetum palustre abounds and Scirpus subterminalis forms dense matted growths.

In Dewey Lake, covering an area of a half acre, is found a form of Polygonum emersum, with most brilliantly red and striking flowers, contrasting well with the usual rose or pink of the species. Philotria, the genuine Canadensis, is very rare except in Pipestone ditch, where it is fine and vigorous. Here also Myriophyllum verticillatum is rare. Cerabophyllum has been found only once in Magician.

Coming to our Fifth District, the oak and hickory growth, we find the

poorest soil and the smallest number of striking plants, and yet a few are most noteworthy. The hickory mentioned is Hicoria microcarpa of Britton's flora. Prof. Sargent practically ignores this species, passing it off apparently as a variety of H. glabra. It is very distinct and characteristic, beautiful in form, very fragrant of fruit, which is sweet but perfectly unsatisfactory by reason of the difficulty of extraction. Liriodendron is found occasionally, and Sassafras has become in old vacated fields and along fences a veritable weed. The most striking herbaceous plant is Frosera, a photograph of which is shown. On a gravelly ridge one mile north of Magician, blooming plants were found by the hundred in 1905. Not one was found in 1906, and only half a dozen young plants. The plant has an enormous root and it certainly does not bloom until the third year, and perhaps later.

Several root parasites are common and interesting. Conopholis grows in clusters, invariably beneath oak trees, and is an oddity. Monotropa, both white and pink, is very abundant, blooming from July to September. Corallorhiza multiflora is very common in all oak timber. Several Dasystomas, by some considered not parasitic, are most conspicuous additions. Smilax rotundifolia forms many a forbidding clump, and Meibomia bracteosa is at home. A very rare orchid, Triphora, has been found in two spots, growing in thick oak leaf mulch. Another rarity, or at least a plant most difficult of discovery, is Aristolochia serpentaria, found only in oak woods of Magician Lake and bearing only cleistogamous flowers. A sunny slope in this same wood yields Draba verna. Mesadenia atriplic folia, three Lactucas, several Hieraciums and Solidago neglecta are the more interesting composites. Many leguminous plants, notably Lespedezas, Cracca, Vicia cardiniana and Lupinus frequent barren open knolls. One single location has been found for Kouhuistera, near Crooked Lake.

The beech and maple land could hardly support a more different growth if removed geographically far distant. It may be explained that while this forest runs across the northwest part of the survey at a distance of only five miles from my cottage base, I never really entered the area until 1906, and my surprise was boundless. Huge trees of beech, hard maple, basswood, and occasional hackberry, coffee beans, black cherry and red elm, were contrasting enough with my oak groves, but when my looks came down to a lower stratum of asimina, fairly dark with bloom, Sambucuspubens, Euonymus atropurpurus and Xanthoxylum, it was interesting, and when I found the earth clothed with such (to me) almost unknown species as Erythronium Americanum (out of bloom), Trillium declinatum (see revision of this genus), Galeaorchis spectabilis, Aplectrum hyemale by dozens and fifties. But pause here to note that the yellow-green form of Prof. Underwood's N. Y. station is the *only* form found here. Asarum reflexum, actasa alba, Caulophyllum are common but not peculiar. But look at that great mass of leaves with gold spots here and there. Surely Stylophorum en masse, my first sight of the plant, and everywhere the leaves of Bicuculla Canadensis. Digging into the leaf mold the yellow "cones" are sown broadcast, so that there is one or more for every six inches. Beautiful to behold are the myriads of Viola Canadensis, never seen before except in Canada. Plants are often two feet in height. Sanguinaria was evidently a common flower in March and April. Geranium Robertianum is as common as Viola, and fairly saturates the air with its peculiar heavy odor. One Panax quinquefolium graced the scene. Erigenia in fruit was found in a few spots. Twice before I met this species, once at Naperville and once at Champaign, Ill. Great masses of Hydrophyllum Canadense in leaf with small flower buds told of

the lateness of its bloom. H. appendiculatum and H. Virginicum associate with the former, the former very scarce. In the fall Leptamnium was everywhere, an odd and interesting form.

An interesting offshoot of this beech flora is found on the Magician islands "Maple," "Hemlock" and "Rattlesnake." The former has lost its virgin character and has not, therefore, been explored, but the other two are most remarkable when we consider that neither is more than one-quarter mile from the oak-clad main land. Here beech, maple, basswood, ironwood, blue beech, white pine, red cedar (now extinct), hemlock, paw paw, dogwood and white elm, with a few butternut, tulip trees, cherry, birch, aspen and red maple make the forest growth. It must be borne in mind that the beech forest is five miles distant, yet here are Leptamnium, Aplectrum, Bicuculla Can., Deutaria laciniale, Sambucus pubens and actasa alba. A perfect haven it seems to prove for the latter judging by the number and perfection. A few isolated and peculiar species are found on the two islands. On "Hemlock," and giving the name, are a dozen fine Tsugas. The southwestern limit, I am led to believe. An interesting bit in connection with the inter-relation of plants is that on the old hemlock stumps the striking fungus Fomes lucidus grows. I have met it once before in the hemlock woods of Canada, and its association seems to be with this species. The fern Phegopteris Phegopteris is found here and nowhere else. Carex scabrata is common and peculiar. Cypripedium hirsubum is abundant on both islands, but exceedingly rare in all other localities.

On "Rattlesnake" island a fine clump of Deutaria diphylla is the only station. Equisebum pratense is common. Each island has a flora of about 150 species, many of which are very common and luxuriant, and apparently find the best of environment in which to grow.

In the northeast part of the survey are two isolated areas of white pine, one consisting of virgin timber, so dark and dense that practically nothing grows. One small area of Coptis makes a fine display in May. Two miles southeast is Pine Lake, with a large wooded island abundantly covered with a mixed growth of timber in which pine predominates. Here is an ideal spot for Epigea, but it is wanting. Mitchella fairly carpets the ground. Lycopodium obscurum abounds, and L. lucidulum occurs *once*. This region has not been thoroughly explored and promises some interesting finds.

The beach flora is limited to the lakes "Dewey," "Cable" and "Crooked," and its mate "Round," and to a few ancient beaches now bordering marshes. Here the plants are found in distinct zones, and form a very peculiar association. Three of these floral bands properly belong to the water forms, and from lakeward towards the shore are as follows: Castalia odorata about 1-3 rods wide; Pontederia, 1 rod; Euthamia caroliniana with Eriocaulon and Utricularias cornuta, gibba and resupinata. At the water line are found Populus deltoides, nowhere else seen, and seemingly dependent on water contact for its seed germination, mixed with Salix Bebbiana and S. myrtilloides. These form simply a *row*. Next landward is a belt of 2-3 feet of Viola lanceolota, then comes a strip of Spirea Etomeutosa, rose and white forms a rod wide, the outer margin gay with apius, and in late summer fairly dotted with Gerardia purpura and G. aspera and heavy with the perfume of Gyrostachys cernua. This belt is broken on Cable Lake by a gravel point covered to the water with Cassia nictitans, elsewhere absent from the whole region. This point also is clothed with Juniperus Virginiana, also an isolated occurrence.

On some of the dry or dead lake shores, notably on what is called Frog

Lake and Fox Lake, are large patches of Viola fimbriatula, blooming in April and May, when one or two inches high, but in fruit becoming a robust plant with leaves six inches long. Here, too, is found Bartonia tenella, an odd looking plant, very inconspicuous. Mixed throughout the plants of these beaches, Xyris montana and flexuosa abound; so common is the latter in Mud Lake bed that whole areas are yellow in the morning hours, and alongside will be a white patch of Eriocaulon or Rhyncospora alba, with here and there a great bunch of R. corniculata. A sandy spit on Crooked Lake yields Dasystoma pedicularia in masses, and further south on the same lake Polygala polygama grows the finest cleistogamous flowers ever seen. On Round Lake Elatine abounds in the mud in about one-half inch of water.

The last region to bear special mention is the steep, often precipitous wooded bank bordering Cable and Crooked lakes on the south shores. Peramium pubescens occurs once in a small cluster, Pyrola secunda is frequent, Cornus circinata is occasional, Campanula rotundifolia is exceedingly abundant, looking far different from the cliff form of northwestern Illinois. Here too Amalanchico Canadensis makes gay in spring and bears very large crops of fine fruits in July.

In addition to the isolated cases mentioned above a number more may be added, overlooked or of doubtful plant association. Lycopodium clavatam is found in *one* small area of a dozen plants on Dewey Lake; Melampyrum lineare adjoins it on the west. Hibiscus moscheutos grows in a swamp near New Buffalo, gay with bloom August, 1906. Juniperus communis is found in a pasture east of Magician Lake. Ipomœa pandurata, one plant on the border of Dowagiac swamp. Cheladonium majus, before named, occurs once, one plant. These examples will suffice to show that the full exploration of any region will demand that every rod of ground be traversed, and gives abundant hope of many new finds in days to come.

A few words in conclusion may be worthy of attention. To date the 60 square miles have yielded 1143 species, and it is certain enough remain to swell the total to 1200, a remarkably good showing for an inland station without rock formation or sandy littoral. Some 90 species have been found woody enough and large enough to make canes. The rare forms are well protected by environment from destruction, and bid fair to remain for many years. The excessive area of bog marsh and lake favor many forms. The very many isolated examples lends itself as a difficult problem for solution, and it is, perhaps the most fascinating feature of the plant distribution. I am strongly inclined to believe that some forms have been artificially spread by the Indians, as this people used, and do so still, many species for medicine that we more highly enlightened ignore. For example, Migbomia Michauxii is a celebrated plant for some form of kidney trouble, and always grows suggestively in "clearings" in the woodlands.

Another matter of much interest is the growth of many plants in situations not recorded in our authorities, which simply means we have much to learn about the life histories of many forms, and will probably conclude that the plant organism is a much more elastic creation than we once believed, and capable in a wide range of fitting itself for inhabiting diverse and seemingly opposite locations with an equal degree of success.

A last word is in the form of a plea for the intelligent preservation of interesting plant localities through the agency of clubs, academies or the liberality of wealthy men, patrons of science. "Rattlesnake Island" well illustrates what may be accomplished. It lies but forty rods away from Maple Island, the summer resort of Dowagiac, and yet it is an untouched wilderness. In

April Trillium grandiflorum grows veritably by thousands, of a size and color richness rarely equalled, and mixed plentifully with Cypripedium hirsutum, Nunlana grandiflora, Actæa, Caulophyllum, Viola papilionacea, Labradorica and Blanda. Beautiful spot, long to linger in the memory, and existing simply because it can only be reached by boat, and therefore, as yet, is not ruined by a habitation. But not for long, probably, will the paradise last. The writer has often thought of a stock company of men and women animated by *love* for *plants* subscribing capital enough to buy up such places for the perpetual use of the flower lover, and realizing as profits the satisfaction of seeing our rare native plants left undisturbed to flourish and live out their beautiful lives in peace and safety. Utopian notion, but after all not an impossible one. The time for such action, however, is short, and the chance will slip ere we are awake enough to grasp it.

Chicago, Ills.

CONTRIBUTION TO THE BOTANICAL SURVEY OF THE HURON RIVER VALLEY.

ALFRED DACHNOWSKI.

RAVINES IN THE VICINITY OF ANN ARBOR.

The following here presented is the outcome of study in the field carried on during the summer and autumn of 1904, and supplemented by further work of a more recent date at the suggestion of Dr. George P. Burns, to whom the writer desires to express his indebtedness for much helpful advice. As a preliminary note for an investigation of the casual relation existing between habitat and plants in this vicinity, the present paper includes the ravines situated along the bluff near the river east of Ann Arbor, in the wooded section known as School-girl glen, and the ravines in Cascade glen and near Foster, distances three and five miles (18 km. and 30 km.), respectively west of Ann Arbor. The objects of this study were to trace out the chief plant associations, and to correlate their distribution with the various ecological factors active in this region. Primarily these data are to be introductory to a more detailed and extended study, under measured conditions, of the varying activity of plants, as individuals and as associations, i. e., the attempt is made at field work in experimental physiology. In addition, though these floristic notes do not complete the needed investigations, it is expected that some light may be thrown on the probable succession of local vegetation. Hence, as a record for comparison of future changes, or an endeavor to indicate in a general way some of the conditions involved, a local study of this kind seemed desirable.

The soil of the Huron river valley is throughout of glacial origin. In this vicinity the numerous rounded morainal hills and similar depressions, the characteristic features of a drift area, betray the youthful topography; and an interesting display of dynamic phenomena is everywhere apparent. The river is bordered by banks 80 to 250 feet (24 m. to 76 m.) high, but seldom reaching more than 300 feet (90 m.). The slopes are more or less gradual. Details of general geography, the geology and topography of this region have been so well treated by several writers, that to avoid reiteration, reference is made to the work of Leverett (1), and the papers of Reed (2), Weld (3), and Brown (4).

Variations in climate are not very considerable. Here also referring, for a more detailed account, to a recent paper (5), the following are the chief climatic features for Ann Arbor (*): The winters, marked by a diminution of precipitation, are relatively mild as compared with other countries. Usually the freshets during March and April are less decided than during July and August, at which time the highest water occurs after the heavy rains; the temperature is at the highest also. This year (1905),

1 Leverett, F. The glacial formations and drainage features of the Erie and Ohio basins, Mon. 41, U. S. G. S.

2 Reed, Howard S. The Ecology of a glacial lake, Bot. Gaz., 34: 125-139, 1902.

3 Weld, Louis H. A peat bog and morainal lake, Bot. Gaz. 37: 36-52, 1904.

4 Brown, Forest, B. H. The Plant societies of the bayou at Ypsilanti, Michigan, Bot. Gaz. 40: 264-284, 1905.

5 Transeau, E. N.

* Comparative data taken from the Annual Summary of the Michigan section of the U. S. Weather Bureau Climate and Crop service.

however, the heaviest rainfall occurred in March. Low water is more frequent in November, gradually increasiing until the ground is frozen. The prevailing rains and winds are from the west and south-west, the winds averaging an hourly velocity of about ten miles (160 km.) for the year 1904, and a maximum velocity of 56 miles during July. The number of rainy days is considerably larger than the number of clear days.

Among the chief factors governing the distribution of plant associations the edaphic and physiographic agencies should be considered also; but here, as with certain climatic data, the importance of these features is best dealt with in the particular description of the localities studied. Neither is it necessary to discuss the early history or the varieties of ravines, since this is set forth in the excellent work of Cowles (6).

Of the ravines studied thus far in this locality, four have been chosen for a preliminary report, on account of the prominence of four phases in ravine processes. For convenience they may be treated under the following aspects: (1) a locally typical ravine; (2) a ravine influenced by man; (3) a ravine of arrested development due to captured territory; (4) a rejuvenated ravine. As illustrations of dynamics in botany no better examples around here could be cited. What additional phases may be present, the brief period of investigation has made impossible to show. Proceeding now to a more detailed account of the ravines and their vegetation, we may conveniently follow them in their natural order of succession.

I. A LOCALLY TYPICAL RAVINE.

The crest outline of the ravine in School-girl glen is approximately that of the 860 feet (260 m.) contour line, (above sea-level) (*), leading into the Huron river by a north north-eastern direction; 1100 feet (330 m.) can be regarded as the length of it, while near the mouth the greatest width is about 300 feet (90 m.), and the depth 110 feet (33 m.). Surrounding the ravine on the east, south and west side and sloping into it, is a peach orchard several acres in extent. The soil consists of a heterogeneous sandy loam inclining in places to a clay structure, and occasionally with a large per cent of gravel. The ravine has been cleared somewhat about twenty years ago, and the consequent changes doubtless have led to a marked modification in vegetation. But the undisturbed trees and the characteristic physical conditions have been effective in the restoration of the original flora, and today the ravine presents a fairly advanced stage in the process. The water entering it is derived chiefly from drainage during seasons of maximum precipitation and, by an underground channel, from a spring near the head of the ravine. Bordering the east and west side occur (†) Corylus americana, Cratægus spp., Rhus hirta, R. glabra, Rubus nigrobaccus, R. canadensis, Helianthus divaricatus. A dense growth of Solanum dulcamara, Vitis vulpina, Sambucus canadensis, Micrampelis lobata, Hystrix hystrix

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1 Cowles, H. C. The physiographic Ecology of Chicago and vicinity. Bot. Gaz. 31: 73-81.

* A topographic map, known as the "Ann Arbor Quadrangle," has been recently completed and published by the U. S. G. S. in cooperation with the Geol. survey of the State of Michigan.

† The nomenclature is that of Britton's Manual of the Flora of the Northern States and Canada, 1901.

with Typha latifolia, Carex retrorsa, C. hystricina, C. rosea, Scirpus atrovirens occupies the area between. The more hydrophytic of these plants owe their presence to the spring near by.

As the ravine widens and deepens a variety of trees become dominant. The vegetation as a whole is that of the "Bluff society," but the series of changes taking place downward is so rapid that definite societies cannot be distinguished except in the more extreme conditions, i. e., where the vertical succession begins with a bluff society and culminates in a flood-plain society. The most characteristic trees of this bluff society are Quercus velutina, Q. alba, Hicoria minima, H. glabra, H. ovata, Juglans nigra, with an occasional elm (Ulmus americana), some ash (Fraxinus nigra), and poplar (Populus tremuloides, P. grandidentata.) The dominant shrub is Corylus americana; several others occur, the chief of which are Viburnum lentago, Ribes cynobasti, R. floridum, Celastrus scandens, Cornus stolonifera, C. alternifolia, Dioscorea villosa, Rhus radicans, making up an association characteristically mixed and densely vine-clad. Dependent upon the protection and the shade of the trees and shrubs are Collinsonia canadensis, Phryma leptostachya, Scrophularia marylandica, Helianthus decapetalus, Caulophyllum thalictroides, Geum canadense, Geranium maculatum, and the usual vernal forms such as Thalictrum dioicum, Sanguinaria canadensis, Trillium erectum, Podophyllum, Anemone, Viola, etc.; also various mosses and liverworts.

A striking difference from this condition is found in places where lateral erosion is greater. These sections may be compared to a denuded locality whose plant covering has been recently laid bare, i. e., during the early spring rains. The soil, a sandy clay, contains approximately 2 % to 3% of water more than the adjoining upland, but about 4% less than the shaded sections within the ravine. Subject to more exposed conditions, especially with reference to climatic factors, and differing also as to water content and soil temperature, the sections are particularly adapted to the study of invasion, consequent competition, and succession. The vegetation near the crest consists of Rhus sirta, Rubus canadensis, Solidago canadensis; further down Solanum dulcamara, Sambucus canadensis, Vitis vulpina, Verbena urticifolia, Mentha canadensis, Potentilla canadensis, Alsine media, Nepeta cataria, Dioscorea villosa, Cornus stolonifera. Where the soil is more sandy and contains a larger per cent of gravel, the flora is that of the adjoining hill; the plants just mentioned are replaced by Onagra biennis, Apocynum androsæmifolium, Linaria linaria, and various thistles, weeds and grasses. Marked differences are seen from year to year as the action of erosion or the influence of the invaders becomes more effective.

Where the slopes become better covered with humus, and the shade of trees is dense, protection from rapid changes in temperature and moisture is more pronounced, and the vegetation also is more luxuriant. But though topography and soil-water content, as determined by the underlying compact till, are two of the necessary and dominant factors for the development of a mesophytic vegetation, the changes in vegetation and the actual grouping of the plants into minor associations depend upon various factors—both physical and biological. It may be of interest to point out the chief species occurring in areas of very similar conditions of soil and topography. For example, the notes of a cross-section taken from a station about 700 feet (212 m.) from the head of the ravine contain among others the following species on the east side: Meibomia grandiflora, M. marylandica, Aster lateriflorus, A. lævis, A. macrophyllus, Rudbeckia laciniata, Ratibida pinnata,

Heliopsis scabra, H. helianthoides, Helianthus decapetalus, H. divaricatus, Monarda fistulosa, Leptandra virginica, Hystrix hystrix, Coreopsis tripteris, Asclepias exaltata. No trees are found here. A few feet farther down several oaks, (Ouercus velutina) occupy aposition about midway between the upper and lower margin of the slope. On this cross-section the vegetation above and around the oaks is distinctly xerophytic and light-loving in character; the plants within the shadow cast by the oaks, and toward the lower edge of the ravine are Leptandra virginica, Coreopsis tripteris, Hamamelis virginiana, Vagnera racemosa, Dioscorea villosa, Vitis vulpina, Aster lævis, A. prenanthoides, Collinsonia canadensis, Mitella dyphilla, Asplenium filix-fœmina, Osmunda cinnamomea, Adiantum pedatum, and various mosses, such as Hypnum and Mnium. A similar section on the west side, under more exposed conditions, contained among others Rhus hirta, Pteris aquilina, Euphorbia corollata and Apocynum cannabinum dominant, while toward the more shaded environment were seen Smilax hispida, Corylus americana, Pteris aquilina, Heliopsis scabra, Dasystoma lævigata, Euphorbia corallata, Verbena urticifolia, Solidago canadensis, Onagra biennis, Hystrix hystrix, and at the base Salomonia commutata, averaging a height of 6 to 7 feet. The differences in temperature between the upland and the base of the ravine vary from 2½°-9°C. on sunny days; on cloudy or windy days the differences are less. Occasionally when the direction of the wind is from the north the reverse holds true, i. e., the temperature within the ravine is from 1½°-3° higher than that of the adjoining fields. The soil contains from 12% to 14% organic matter and a physical water content averaging 3% to 5% higher as compared with the upland. It is inadequate to express these changes in vegetation in terms of water content merely, since various factors are involved, and the results arise from the united action of these (7-8). Conditions obtain whose water-content and characteristic distribution of plants is largely determined by light; the development of plants as well as their structure and density change in accordance with the varying light intensity. The *reactions* of the plants are equally great and profound—the habitat in turn undergoing marked changes also. For instance, the increasing diffuseness of light in some places, due to luxuriant growth, precludes nearly all undergrowth, increases the humidity of the air, thus lessening again aeration, transpiration, and absorption of soil-water—reactions through which light, humidity, temperature and soil-water content are most distinctly modified. In other places the plants produce seeds and seedlings with difficulty. The decomposed remains of an earlier vegetation lead to mechanical and chemical changes in the soil. But though increasing the soil in nutrition content and water-content, in their extent these changes are more effective toward breaking up the flora into a heterogeneous formation, accompanied with a frequent changing of one dominant group by another. In other and dryer situations the more mesophytic of these plants differ in appearance, but especially in the extent and branching of the root system. The same physiological adjustments, though in a converse sense, hold true for the more xerophytic plants in the moister regions of the ravine. However, it is not the purpose of this paper to indicate in detail the extensive physiological reactions both functional and structural occurring here. On comparing the composition of these societies with that of others, it is clearly seen that the mutual interaction of plants and environment leads

7 Warming, E. Lehrbuch der ökologischen Pflanzengeographie, 1896, p. 105-106.
8. Schimper, A. F. W. Pflanzen-Geographie auf Physiologischer Grundlage, 1898, p. 204-205.

to grouping, which otherwise would be limited to and depending upon soil water factor alone, and hence would have been either very limited or else wholly absent.

Just as striking is the character of the vegetation in a smaller ravine which enters into this one from the west a few feet farther down. Here as elsewhere the behavior and arrangement of plants varies because of several factors; principally on account of modified relations between humidity and insolation due to the condition of the plants themselves, the reaction of plants in preventing erosion, in binding and enriching the soil. The accumulation of humus in one place, the destruction of it by fire in another; the no less important condition of habitat as determined by the trough-like or the talus-like character of the slopes, north and south exposure, prevailing westerly direction of rains; characteristic seed dissemination and germination, and the physiological condition of the invading plants—these, and more, make it obvious that the analytic treatment, or the explanation on the basis of one or few factors is not sufficient. Not only is it unsatisfactory to study the habitat as such, i. e., as it presents itself statically at the time of investigation; not even the standpoint of physiographic change and the consequent movement of a dependent fauna or flora is adequate to account for the changes and distribution of life in this region. A knowledge of the reactions of plants upon their environment—the functioning between organisms and environment—is equally essential for an interpretation of the habitat if dynamically considered. This will not be surprising to any one who approaches the problem from the physiologist's(9) point of view, and recognizes that a fuller account of physiological activities and reactions would clearly include an answer to a more satisfactory understanding of such terms as "habitat," "dynamic," "process." However, quantitative study, as well as careful and definite analysis of the conditions must be continued for some time in order that the various changes and phases may be correlated with the factors in question, and the extent of modification due to them may be recognized.

Worthy of note is the flora occurring at ground water level. This point is about 250 feet (76 m.) from the margin, and about 30 feet (9 m.) above the level of the river. During the months of July, August and the early part of September (1904) temperature readings, taken about three o'clock in the afternoon both at ground water level and at a point 65 feet (19 m.) directly above on the upland of the eastern slope, showed an average difference of 5° and 6.5° C., for air and soil temperature respectively. The physical water content of the soil averages slightly more than that last mentioned. The more alluvial character of the soil, together with increased humidity and the continual presence of flowing water favor a dense luxuriant flood-plain region. The following are a few forms to be found here and in the direction toward the river margin: Juglans nigra, J. cinerea, Tilia americana, Ulmus fulva, U. americana with Carpinus caroliniana, Malus coronaria, Salix discolor, S. lucida, S. nigra, as a tension line nearer the water, and Prunus americana, Acer saccharum, Cornus candidissima, C. alternifolia, Hamamelis virginiana higher up. The most common associated herbaceous species are: Geum strictum, G. canadense, Sanicula marylandica, Equisetum hyemale, Galium triflorum, Smilax herbacea, Rudbeckia laciniata, Urticastrum divaricatum, Solidago flexicaulis, Deringa canadensis, Collinsonia canadensis, Campanula americana, Washingtonia claytoni, Parthenocissus

9. Clements, F. E., Research Methods in Ecology, 1905.

quinquefolia, Nabalus altissimus, Cassia marylandica, Physalis heterophylla, Uvularia perfoliata, Falcata comosa, Phryma leptostachya, Oxalis stricta, Micrampelis lobata, Prunella vulgaris, Lobelia syphilitica, Impatiens fulva, Bidens, Mitella, Viola, and others. Interesting also is the large number of sterile plants to be found here.

The ravine has not escaped human influence. The repeated burning of the slopes near the mouth has strengthened the xerophytic flora. On areas in which denudation of that character has affected the surface, the clearing societies consist of Helianthus divaricatus, Aster laevis, Salix humilis, S. tristis, Solidago canadensis, S. rigida, Lespedeza frutescens, L. violacea, Lacinaria scariosa, Rhus glabra, Euphorbia corollata, Viburnum acerfolium on the east side, and of Rhus hirta, Pteris aquilina, Vaccinium vacillans, Apocynum cannabinum, Monarda fistulosa, Vagnera racemosa, Pimpinella integerrima, Agropyron repens, Andropogon furcatus and others on the west side. This society is maintained until the seedlings of trees with deeper shade are capable of supporting themselves. Usually Rhus hirta and R. glabra get the ascendency, associated in some places with Corylus americana and Pteris aquilina. The latter develops best on slopes in such condition, though luxuriant also when near or under the shade of young oak and hickory saplings. As the shrubs and grasses add their share of vegetable debris to the soil, making it slowly richer in organic compounds, and the capacity to hold water, heat and oxygen increase, the flora at the lower margin creeps up again. Oaks (Quercus velutina being the most common) and hickories soon become dominant, to be followed in arrangement by poplar, basswood, elm, maple, and the associated shrubs and herbal undergrowth. Such signs of repeated invasion of mesophytic plant societies are frequent. Even though the changes induced by fires are considerable, as a rule they seem rather to assist in the direction of the original mesophytic association, and to prepare the ground for seeding.

II. A RAVINE INFLUENCED BY MAN.

At a distance of about 120 rods (600 m.) to the west, another ravine is situated in this section. Its general direction is more to the north-west, with slopes averaging an incline of 30° to 35°. The conditions of the present association, briefly stated, seem to be these: The slopes, and most of the hill land adjoining the ravine are pasture. This pasture, though extensive, is not natural; it plainly shows that it has been the outcome of various agencies, of which the regular cropping and treading by cattle, and the repeated fires seem to have been the more active factors. Extensive thickets of Corylus americana and of various species of Crataegus, also of Rhus hirta and R. glabra occur here, no doubt the forerunner of an encroaching flora similar to the one in the neighboring ravine. The outposts of the new flora are rapidly advancing, running down the slopes of the ravine from the east. Beneath and about the invading shrubs, the grass-land takes on a somewhat different appearance. Extermination increases, as shrubs and dependent herbs, species similar to those of the ravine above mentioned, become more and more compact. Several trees (Quercus velutina, Juglans nigra, and Ulmus fulva, with an occasional willow) are standing isolated with dependent herbs checked in growth by the grazing cattle, or stunted and suppressed because of occasional cultivation. Interesting is the effect of artificial drainage on the habitat of some perennial grasses. The soil is slowly removed by the action of a spring near the upper margin of the ravine. The

plants check the numerous rills due to the downward flow of the water, causing deposition of part of the eroded soil. Accelerated growth, partly of the plant, partly on account of the fixation of soil, gives rise to the well-known hummocks of swamps. Building, enriching the soil, and occasional fires are represented by many and diverse changes. The repeated burnings do not injure so much the vegetation of the pasture, as the invading plants of the adjacent woods. However, it is necessary to investigate more definitely the various factors and stages determining the invasion between these two areas. This ravine and several others of a like type, excellently illustrate that the stage of a process in ravine life is more often due to biological than to physical causes, and that a description or an understanding of a life history of plant associations is inadequate, unless the human factor is taken into account. As an influence for introducing and eliminating many species, and complicating or interfering with the scene of action of ravine life, the human agency is certainly of increasing importance.

III. A RAVINE OF ARRESTED DEVELOPMENT DUE TO CAPTURED TERRITORY.

In Cascade Glen, as in the preceding section, and the one next to be described, woods occur some distance from the edge of the bluffs and down to the river margin. Throughout the whole area oaks and hickories are the dominant trees. The region is topographically very much like that of Schoolgirl Glen, except that the direction of the first and larger ravine is more parallel with the bluff, i. e., in a direction west to east-north-east. Springs and the effect of cultivation in adjoining fields have been the cause of the more rapid development, thus aiding in the capture of the neighboring territory, forcing a shifting of divides, and leading the increased drainage into the main ravine stream bed. This directed the formative forces into new channels, and resulted in the arrested development of neighboring ravines. The physiographic features are not so marked in the larger ravine as in some others of this vicinity. The vegetation is similar to that of the ravine first described, but noteworthy is the fact that the flora is increased in variety by a large number of herbaceous plants. The lowland of the ravine is damp, shady, and rich in humus. The shade of the trees is much greater on the south than on the north side; hence the flora of the former is much richer in species, especially of the early flowering kind, while the flora of the north side contains a high proportion of late flowering Compositæ. This difference is also observable in regard to ferns, mosses and liverworts. A few preliminary experiments show that the water content of the soil depends largely upon drainage, the firmness of the soil particles, and upon accumulated humus; it is the principal element in determining the character of the growth, while the ecological distribution of the vegetation is determined by conditions of water content of soil as modified by topographic environment, and plant reaction. Various other ecological factors such as the historic one, are of importance also, but the data on hand are so limited that at present a consideration of these and other questions can not be attempted.

As an example of arrested development due to captured territory, the ravine nearest the headwaters of the one just mentioned, is of more special interest. The ravine indicates various changes, all of which have an evident effect on the vegetation. The conditions of plant life are very distinct; the amount of water available is scanty, partly on account of the divide existing, partly because the vegetation carpet reduces instability of soil, and erosion is confined to side-wash. Where soil and vegetation are more com-

pact, even this side-wash is reduced, largely on account of the delayed downward flow of water, and the consequently greater absorption of it by the soil. Absence of vertical erosion and of meandering due to ravine rills and streams has increased the favorable conditions necessary for plant life, but the limited drainage is not advantageous to the formation of a mesophytic flora, either of vernal or estival forms. About midway the outcropping of an impervious and compact clay, which underlies the whole region, and appears elsewhere at the surface, is important, because of the relations existing between the upper and lower soil types and the associated plant societies. There is a slow but constant flow and percolation of water, and the distribution of plants as influenced by conditions of soil moisture gives rise to important differences. A profile was made, shown in Fig. —, and is added here through the courtesy of Dr. Burns.

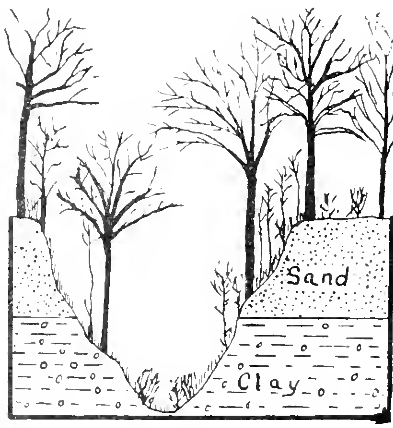

FIG. 1.

The moisture in the soil is retained for considerable depth. Tracts of low, wet ground occur at the mouth and such moisture-preferring plants as Impatiens fulva, Gentiana flavida, Solidago flexicaulis, Equisetum hyemale, Eupatorium ageratoides, Pedicularis lanceolata, Lobelia syphilitica, Aster lowrieanus are frequent. Mosses, liverworts and fungi are well represented. The intermediate zone is a dense profusion of ferns, such as Adiantum pedatum, Asplenium felix-fœmina, Onoclea sensibilis, O. struthiopteris, Osmunda regalis, O. claytoniana, O. cinnamomea, Dryopteris acrostichoides with Pteris aquilina and Phegopteris hexagonoptera higher up. The arrangement varies from place to place. Shrubs such as Corylus americana, may be thickly clustered; in other parts a loose growth of oak and hickory saplings, or of Cornus candidissima, with climbers such as Celastris scandens, Dioscorea villosa and Smilax herbacea, covers the ground. In passing upward the herbaceous vegetation includes Thalictrum dioicum, Vagnera racemosa, Eupatorium purpureum, Smilax hispida, Meibomia grandiflora, and nearer the divide are found Meibomia rigida, M. Michauxii, Lespedeza violacea, Vaccinium vacillans, Rosa humilis, Helianthus divaricatus, Salix humilis, Corylus americana, Rhus hirta, and several perennial grasses and composites, already indicated in the first ravine described.

IV. A REJUVENATED RAVINE.

Of greater interest from a dynamic point of view, is a ravine situated across the river, on the side opposite the city water works and near Foster. The surface of the region in that vicinity is typically morainal. The ground is undulating and hilly, the highest point running up to 300 feet (90 m.) above river level. The hills are rounded and at times occurring in parallels. The depressions are of like characteristic. Many of them are occupied by swamps or show deposits of peat several feet in thickness and now covered by soil of similar depth. Springs occur, but running water and streams are few, scarcely any outlets being visible except such as have been produced through ravine erosion.

The drainage from these hills finding its way into the main ravine channel is comparatively large. The soil is heterogeneous, consisting principally of sand and gravel and boulder clay underlying the whole region, with frequent pockets of fine sand or extensive beds of marl. Ground water level and water-content of soil vary accordingly. The seepage springs along the soil line plainly reveal the importance of soil water-content as an influence in the distribution of plants. The ravine has a length of about half a mile (3 km.), but only a part of this is wooded. At the mouth the width is nearly 450 feet (136 m.), the ravine fronting the river from a direction north to south. It seems that a phase of ravine life existed here similar to the one last described; and that at some not distant period a sudden increase of drainage area occurred, which, no doubt, was due to the tapping of the depressions and swamp areas north of the bluff. The effect of cultivation has been scarcely less significant.

That the earlier condition was but temporary is best seen in the changes now taking place. Increased drainage and the consequent entrenched meandering of the ravine stream—averaging in some places a depth of 5 to 6 feet—again are causing vertical banks, both in the old flood-plain of the ravine as well as in the adjoining slopes. In these, though of a tenacious blue clay, the eroded parts average a height of 15 to 25 feet. The size of the trees, moreover, is clearly indicative of former favorable conditions, while the activity of the erosion forces now present, is revealed by leaning and fallen trees.

At the mouth of the ravine occurs an extensive zone of sedges and willows. An interesting feature in the sedge zone is the relative abundance of Chara, the relation of which to local marl formation has been recently described by Davis (10). The plant gets its lime from the water and forms large patches of fine-grained marl deposits. Where the water comes with considerable calcareous matter from the neighboring marl-beds, incrustations develop around roots and mosses. Nearer the ravine stream Salix petiolaris, S. rostrata, S. lucida, Populus tremuloides, together with Cornus stolonifera, various species of Crataegus, Vitis vulpina and Celastrus scandens form a loose thicket. The ground is little shaded and such plants as Gentiana crinita, G. quinquefolia, Aster puniceus, Prunella vulgaris, Euonymus obovatus, Parnassia Caroliniana, Impatiens fulva, Urticastrum divaricatum, Nabalus albus and Cystopteris fragilis are frequent. Here especially the relation of the impervious clay layer beneath to the distribution of these plants is evident. On the banks about the mouth Vaccinium vacillans and Gaylussacia resinosa are dominant.

10 Davis, C. A. "A Contribution to the natural history of Marl," Geol. Surv. of Mich. 8:65-90-1900-1903.

Passing northward, the characteristic vegetation found to prevail throughout the upper part of the ravine and the occasional tributary ravines, consist of Juglans cinera, J. nigra, Hicoria glabra, H. ovata, H. minima, Tilia americana, Quercus alba, Q. velutina, Q. rubra, Q. Alexandrii, Ulmus americana, U. fulva, U. racemosa, Acer saccharum, A. rubrum, A. nigrum, Populus deltoides, Fagus americana, together with Hamamelis virginiana, Sassafras sassafras, Carpinus caroliana, Ostrya virginiana, Prunus serotina, Opulaster opulifolia, Cornus florida, Benzoin benzoin, Corylus americana, and others. A conspicuous feature is the large number of saplings of red oak (Quercus rubra), maple (Acer saccharum, A. nigrum, A. rubrum), and beech (Fagus americana). As undergrowth, some of the early flowering forms are found. The character of the humus-flora is also noteworthy. Hepatica hepatica, Arisæma triphyllum, Asarum canadense, Actæa alba, are very common; relatively frequent is Monotropa uniflora. Where the physical nature of the slopes makes rapid weathering and erosion impossible the almost vertical clay bluffs, dripping with moisture, have principally mosses and liverworts, while Collinsonia canadensis, Cicuta maculata, Impatiens fulva, Viola and other moisture-preferring plants are found at the base.

The beds of marl occurring here, covered to some extent by a layer of humus have an herbal vegetation differing but little from other places around them. Of the ferns, Dryopteris acrostichoides is quite common, but mosses, such as Climacium, Hypnum and Mnium are more abundant. The water derived from springs near by, and from seepage, dissolves the almost pure limestone beds very rapidly. Considerable sections are thus undermined, producing instability and consequent settling of the beds, and leading finally to the formation of tributary ravines. The calcium carbonate is carried off to the river, but partly met with again in the form of incrustations mentioned above.

As has been stated, the present paper is preliminary to a more extended study of field work in physiology; hence more complete data will be included in another report. But even at this stage, the results obtained make it very obvious that the simplest condition in the life-history of these plant associations is the outcome of a chain of factors. Where no doubt exists concerning the more dominant ecological factor, in concrete cases no one of them can be cited as exclusively determining the character of the local flora. Many differences in kind and arrangement of vegetation are results of the united action of the various ecological factors working in concert, which, in turn reacted upon by the condition of the plants themselves, thus give rise to changes in habitat and consequent distribution of plants not to be attributed either to a changing topography alone, or ground-water level, character of soil, etc. Fully to understand these plant groups we must contemplate them as the result of an ever-changing process (as described and defined above on page —). And if we wish to compare records, the reason should be that we would know *how* the many active factors are involved and related in the process that is going on.

University of Michigan, Botanical Laboratory, April, 1905.

OBSERVATIONS ON THE COLLECTION AND STUDY OF CRATAEGI IN THE VICINITY OF PORT HURON, MICHIGAN.

C. K. DODGE.

Since leaving the University of Michigan in 1870, I have been interested in botany as a recreation. I went to Port Huron, Michigan, in 1875, but did not proceed in a systematic way in my investigations until 1892. I now much regret the valuable time lost. Feeling the need of more outdoor exercise, I proposed to myself to search out, if possible, every plant growing wild within 40 miles of Port Huron, confining myself almost exclusively to flowering plants, ferns and their allies. One of my first troubles was with the thorns. They would not fit the descriptions in Gray. I wrote to Prof. C. F. Wheeler about it and sent specimens. He said I must apply the procrustean method and make them fit, for as yet there was no other way. It seemed there was no end to variation. I naturally enough divided them into groups for my own convenience, Coccineæ, Tomentosæ, Punctatæ, and Crus-galli, afterward adding Molles. The Punctatæ and Crus-galli were not very troublesome, but the Coccineæ, Tomentosæ and Molles were conundrums. I could not reconcile them. It appeared to me that if Torrey and Gray could have seen some of my Molles in the field, the tops spreading thirty feet, limbs touching the ground, with body sixteen inches in diameter three feet from the ground, they never would have said "C. coccinea var. Mullis." The Tomentosæ in particular seemed to me to differ among themselves in general appearance as much as does white oak from bur oak.

About 1895 I heard that a few botanists were investigating the Cratægi. Early in 1900, I think it was, I received a letter from W. W. Ashe, of Raliegh, North Carolina, requesting me to send him specimens of thorns from my locality. I did so, and he was at once interested. He visited me in September, 1901, and again in September, 1902, naming a number of species. Later in 1900 I received a request from Prof. J. W. Beal to collect for Prof. C. S. Sargent of the Harvard Arboretum. I sent Prof. Sargent specimens, I think, in 1903. He also took great interest in them; visited me in September, 1904 and again in September, 1906.

Mr. Ashe apparently dropped his work in Michigan, but Prof. Sargent, having already examined many specimens of thorns from Michigan collected by Miss Emma J. Cole, of Grand Rapids, Kent Co., and in a few other localities, kindly consented to do what he could with the thorns of my locality and other places in Michigan. The main question with us here today is as to how we can best solve the question of Cratægus species for our state. I think Prof. Sargent will kindly continue to help us if we will only do something for ourselves. His first paper on Michigan Cratægi has been prepared, is now submitted to us, and will soon be printed by the Michigan Board of Geological Survey as a contribution to the biological survey of the state. Information regarding this paper may be had from the State Geologist, Alfred C. Lane, Lansing.

The specimens of Cratægi from Michigan heretofore collected and placed in the herbaria of the country cannot be relied on. Usually they are badly

mixed up, fruit and leaves from one tree and flowers from another. We must start anew, have type specimens and type trees to refer to. *Fruit, leaf and flower specimens must come from the same tree.* A mistake in this matter cannot be tolerated. If there is any doubt at all about where the tree material comes from, by all means throw it away. Burn it up. The best time, in my judgment, to select trees for study is in September, when the the greatest and most essential differences in fruit and leaves can easily be seen. Pick out healthy and vigorous trees. Use a field book for notes and do not try to get along without one. Have a regular Cratægus book in which all trees are paged and numbered, written up in ink, and into which all field notes are to be finally copied as time will permit. Number and locate every tree selected for observation as carefully as possible, remembering that the general appearance of a locality differs very materially in September and May. Do not rely altogether on tags tied or tacked to the tree, as they are easily lost and there may be great uncertainty. The first vandal of a boy that spies a tag promptly tears it off, and wants to know what foolish fellow has been acting like that. Wind and weather easily destroy them. Carry a small can of good red paint with a prush and put the numbers on in several places. Also with a jack-knife or pocket ax scrape or cut off the rough or outside bark on the north side and mark the number on with a lead pencil. Between the two methods not a tree will be lost. This must be kept up every year in many instances. Be as careful as possible in selecting trees that are not liable to be cut down. Note particularly color, flavor and size of fruit, that is, the thorn apples, so called, height of tree, form of top, diameter of body one or more feet from ground, compound spines, whether spines on branches are very rare, few or plentiful, whether bark is smooth, or rough and flakey, kind of ground in which tree grows, whether trees are alone, in clumps, branched at or near the base, or a number of them from the same root. Those who are skilled in drawing will certainly not forget to transfer to their Cratægus book the form and exact dimensions of the largest and medium sized apples and spines. Many will find much more to record than is mentioned here. Such a Cratægus book with even rude maps locating the trees may be used by others to examine type trees long after we have passed away. My Cratægus book will be deposited in the Carnegie public library at Port Huron. It is well to remember that without doubt, the genus, Cratægus, will sometime hereafter be critically reviewed by botanists.

In collecting fruit and leaf specimens make careful selections, branches if possible 10 or more inches long. Do not press hard enough at first to crush the fruit. Press rather light at first, harder afterward. With careful manipulation one will be surprised at the way in which large fruited specimens, with numerous twigs and spines, can be pressed into shape. Watch carefully the early-fruited thorns. The fruit specimens of most Molles and a few others should be collected, at least in my locality, not much later than from the first to the fifth of September. If later the apples will fall off. Collect fruit specimens of other groups from the tenth to the thirtieth of September, according to the condition of the fruit. Some may be collected at any time afterward before a killing frost. If fine specimens are desired change driers at least once in 24 huours for three consecutive days and use plenty of driers.

In my locality the early-flowering thorns, particularly the Molles, begin to bloom on or shortly after the tenth of May, on Walpole Island, Lambton Co., Ontario, and near Algonac, St. Clair Co., Michigan. Near the city of

Port Huron it is usually at least five days later. From these dates up to the fifteenth of June there is continuous blooming of thorns, ending with the Tomentosæ. All of my trees, numbered and reposrted upon, about 160 of them, are on both banks of St. Clair river and running north along the Lake Huron shore and along Black river in St. Clair county, a strip about 40 miles long and 10 miles wide. Observations during the flowering season must be very carefully made for the reasons suggested by Prof. Sargent in his paper. Mistakes made at this time cause much trouble. We must have an accurate account of number of stamens and color of anthers. Examine and count them and note color in bud, again just before the petals spread and again early in full bloom. In some of these stages the anthers may appear to be white, when in fact they are pink in early bloom. This was found to be the case in some of the Crus-galli group. The color of anthers often fades in early bloom. Be sure not to guess about it. It is far better to wait another year. Select for pressing as large flowering specimens as possible up to ten inches and more in length. As in case of fruit specimens, the twigs and spines, if any, will press down very nicely. If reasonable care is taken it is not difficult to prepare very good specimens. More pains must be taken with the Molles than the others. The young leaves, tender stems, and flowers of the Molles appear to be succulent and are liable to turn black. The fruit is large and often juicy. A little experience will, however, overcome these difficulties.

The recent increase of species in some genera appears rather strange to some of us amateurs. The species in Panicum, Viola and Antennaria have jumped from a moderate to a large number. But the genus Cratægus has certainly outdone them all. In Gray's Manual, sixth edition, ten native species and two varieties are described for the Northern United States. In Chapman's third edition of the Flora of the Southern United States, six species and one variety are added. Britton in his Manual describes thirty native species. Prof. C. S. Sargent in his Manual of the Trees of North America has described and illustrated one hundred and thirty-two species. Prof. Sargent estimates that in any locality alone there are about fifty species, twenty of which are new. The genus has been variously estimated to contain from 200 to 400 species in North America. It has therefore arisen from a very modest number of species to be far more numerous than in Carex, Solidago, Aster, or Astragalus. Many of us wonder what former botanists, species makers, were doing to let so many species escape their attention. The explnaation, so far as I have heard any, is that former botanists overlooked many essential things among the Cratægus forms, that viewing the various forms as they now exist, and proceeding on the same principles used in carving out species in other genera, the recent multiplication of species is proper, necessary, and scientific. Prof. Sargent is certainly proceeding with the greatest caution. So far as possible the seed of every proposed species has been and is being planted in the grounds of the Harvard Arboretum, and will be carefully watched to see whether in each case the new trees will prove true to type. Prof. Sargent tells me that so far as he has been able to test the matter they have proven true. In any event the question of Cratægus species must be worked out in our state. I for one am willing to help do it, and hope other botanists will do what they can. We now have a fair beginning.

Port Huron, Mich.

THE CHARACEÆ OF MICHIGAN.

Ellen B. Bach.

Nitella batrachosperma (Reichmb.) A. Br., Nitella flexilis (L. ex parte) Ag., Chara aspera Willd., C. contraria A. Br., C. foliolosa Muhl., C. formosa Robinson, C. fragilis Desv., C. Hicksii Allen, C. Morongii Robinson, C. Robbinsii Halsted, C. Schweinitzii A. Br., C. sejuncta A. Br., C. vulgaris L.

The above is a partial list of the Characeæ of Michigan. Little attention has so far been paid to the collection of this widely distrbuted group of water plants, though nearly every river and lake in the state contains one or more forms.

Will not plant collectors throughout the state keep the Characeæ in mind during their fruiting season, which varies from May to September, or even later, and send specimens to the University laboratory for identification, that we may complete our list of the species of this state? These plants may be either pressed or kept in 3 per cent formalin or 50 per cent alcohol.

Botanical Laboratory, University of Michigan, Ann Arbor, Mar., 1907.

ON THE DISTRIBUTION OF ACER SPICATUM LAM., AND ACER PENNSYLVANICUM L. IN THE NORTHERN PENINSULA OF MICHIGAN.

CHARLES A. DAVIS.

In rather extensive travels over considerable areas of the Northern Peninsula during two field seasons, the writer has been impressed with the marked differences exhibited in the range and the variations of habitat of the two shrubby species of maple, Acer Pennsylvanicum L., the Striped Maple, and Acer spicatum Lam., the Mountain Maple. In the Michigan Flora, 1904, the distribution of Acer Pennsylvanicum is given as "abundant in the Northern Peninsula, Whitney. Common at Petoskey and occasional as far south on the Huron shore as Alcona Co., Winchell Catalogue; in the interior as far as Houghton Lake. N. and U. P."

That of Acer spicatum is given as "Common in the Northern Peninsula; Alcona Co., Winchell's Catalogue; Crystal Lake, Montcalm Co., Alma; C., N. and U. P." From these notes one would infer that the two species had about the same distribution in the Northern Peninsula, and that they were equally abundant throughout those parts of their ranges in which they occur together. Such is not the case, however, according to the experience of the writer. It is true that Acer spicatum is widely distributed and frequently a very abundant plant in two types of habitat, over most of the Northern Peninsula; it occurs in the dryer parts of swamps and in greater quantity in their borders, and as one proceeds northwards, becomes one of the more important constituents of the undergrowth in the mesophytic forest, often forming dense thickets in and around clearings and at the sides of wood-roads and other artificial and natural openings in the forest. In such places it often is so thick and shades the ground so heavily that it must tend to check, to a considerable extent, the natural reproduction of all but the most tolerant of the dominant forest trees.

The plant in its best development is scarcely more than a tall shrub, 15 to 25 feet high, very tolerant of shade, but flourishing in the better light of the openings, and is worthless for any purpose, the wood being exceedingly brittle and soft, and the diameter rarely as much as three inches. This species is common throughout the region under discussion, wherever the hardwood timber grows, and is not infrequent in the moister parts of the types of soil formerly covered by the pines. It is often abundant in rocky hardwood forests, and upon open talus-slopes, against the bases of steep cliffs, but rarely appears as a crevice plant on the exposed cliffs. It is rarely or never an inhabitant of the wet areas of swamps, but, as noted above, habitually occurs about their borders, especially towards the southern part of the peninsula.

Acer Pennsylvanicum, on the other hand, has a very much more restricted range, both laterally, in that it does not occur so generally, and vertically, because it has much less varied habitat. In the summer of 1905, when attached to the party of Professor I. C. Russell, working in the interior of Menominee county, and in Dickinson and Iron counties, this species was

not seen although a very conspicuous and easily recognized plant, and one well known and constantly looked for. It was not observed in the vicinity of Bessemer, nor around Houghton, where conditions were favorable for its growth, but near Marquette, for the first time, it was seen somewhat frequently in the hardwood forest. Late in that season, during a short stay at Newberry, and a rapid reconnaisance over the region between the railroad and Lake Superior, the species was not observed in the old hardwood forest, or at all, until within five or six miles of Lake Superior, when it suddenly became a common member of the lower story of the forest, and continued so until the vicinity of the shore of the lake was reached, where pines generally replaced the broad-leaved trees. In returning to Newberry, by way of Grand Marais, after a trip of some thirty miles along the beach, the road which was followed ran almost continuously through a hardwood forest, the Hard Maple and Birches being the dominant species. On this trip the species under discussion was abundant for a distance of five or six miles from the lake, and then was seen no more, disappeariag entirely from the woods.

In 1906 a more extended opportunity presented itself to study the region from Marquette north and west, covering a large part of Marquette county, and again it was found that while Acer Pennsylvanicum was of common occurrence in the hardwoods, in the vicinity of Lake Superior, it did not appear in similar places which were a few miles inland. In like manner, in going from Huron Mountain southward into the highland lying in that direction, the species was not seen after the head of the Mountain Lake was passed, although frequent in the woods nearer Lake Superior; this is about six miles south of Lake Superior, and it was not seen in the heavy and undisturbed forests farther south, about the headwaters of the Yellow Dog river, nor in the great areas of practically unbroken forest in the vicinity of, and to the west of Lake Michigamme.

The habitat of this interesting species is the dense shade of the hardwood, or mixed hardwood and conifer forest, on well watered, but not wet, slopes and flats, where it grows associated with the over-shadowing Birches, Sugar Maples, Basswoods, Elms, and frequently, also, the somber Hemlocks, often the only undergrowth, a site for which its broad leaves and spreading top especially fits it. With it, in less dense shade, the Mountain Maple is frequently found and young individuals of its taller growing neighbors.

It is apparent from these observations, that Acer Pennsylvanicum is a plant of rather restricted range in the Northern Peninsula, being confined to a belt not more than six miles in width, along the shores of Lake Superior, on the northern side of the Peninsula, and of undetermined limits on the suothern side. Its habitat, so far as observed, is also restricted to rather dense shade, and moist, well drained soil.

Ann Arbor, March, 1907.

CRATÆGUS IN SOUTHERN MICHIGAN.

C. S. SARGENT.

Professor Charles S. Sargent, of the Arnold Arboretum, Jamaica Plain, Mass., at the request of Dr. W. J. Beal, prepared for publication a paper which embodies the results of his studies of the Thornapples or Hawthorns of Michigan, and the adjacent region. The paper was presented to the Michigan Academy of Science to be published in the present volume of Reports, but in the hope that it might be printed in time for use during the field season of 1907, it was decided to request the State Board of Geological Survey, through the State Geologist, Alfred C. Lane, to include the paper in the Report of the Board of Geological Survey for 1906, as a contribution to the Biological Survey of the State, now being conducted. This request was very kindly granted, and information regarding the complete paper may be had by application to the State Geologist, Lansing, Michigan.

In order that the members of the Academy may have the benefit of the directions for collecting these interesting plants, however, the introduction to Professor Sargent's paper, and his instructions for the collection of usable material are here given. Those who are willing to systematically collect good and complete specimens of Cratægus in any part of the state can materially help in the work of extending our knowledge of the number and distribution of the species of this most interesting genus of trees.

C. A. D.

Professor Sargent says:

In the following paper I have attempted to give an account of the species of Cratægus that are now known to occur in the southern part of the state in the hope that its publication, by calling attention to the richness of the Michigan flora in the plants of this genus, may encourage its more general study.

Southern Michigan forms the western extension of what is perhaps the richest Cratægus region in the world; certainly in no other part of the world where the genus has been at all carefully studied are there so many species as in the territory extending from the valley of the Genessee river in New York, up both sides of the Niagara river and through Southern Ontario into Southern Michigan, and nowhere are there more distinct species.

Of the genus as it occurs in Michigan little is yet known. It has been carefully and systematically studied only on Belle Isle, in the Detroit river, by Mr. O. A. Farwell, in St. Clair county, by Mr. C. K. Dodge, and in the neighborhood of Grand Rapids by Miss E. J. Cole. It is now possible, however, to distinguish fifty-five species, and of these twenty are now first described. Nineteen others briefly described by Ashe from St. Clair county are also described in this paper from material furnished by Mr. Dodge. All the Michigan species described by Ashe have been identified with the exception of C. passena, collected at Port Huron, and probably one of the Flabellatus, C. fallax, from "rocky hills" near Port Huron, and C. borealis, without other locality than "Michigan." The latter species is given in

Beal's Michigan Flora, 1904, "St. Clair Co., W. W. Ashe; Keweenaw Co., O. A. Farwell."

In Beal's Michigan Flora, 1904, the following species of Cratægus, besides those mentioned, reported as occuring in Michigan by various collectors, have not been seen from the state by the writer:

C. acutiloba, Sargent, Detroit, O. A. Farwell.
C. altrix, Ashe, Detroit, O. A. Farwell.
C. brevispina, (Dougl.) Farwell, Keweenaw Co., O. A. Farwell.
C. coccinea, L. Common throughout.
C. Crus-galli, L. Common throughout.
C. decans, Ashe, Detroit, O. A. Farwell.
C. filipes, Ashe, St. Clair Co., W. W. Ashe.
C. macrantha, Lodd. Common throughout.
C. nuperia, Ashe, Detroit, O. A. Farwell.
C. obtecta, Ashe, Detroit; St. Clair Co., W. W. Ashe.
C. onusta, Ashe, St. Clair Co., W. W. Ashe.
C. pastora, Sargent, Detroit, O. A. Farwell.
C. prunifolia (Marsh), Pers., Detroit, O. A. Farwell.
C. pubipes, Ashe, St. Clair Co., W. W. Ashe.
C. redolans, Ashe, Detroit, O. A. Farwell.
C. rotundifolia (Ehrh.), Borck., Grand Rapids, Island Lake, C. F. Wheeler.
C. virella, Ashe, St. Clair Co., W. W. Ashe.

Judging from the material which I have seen from other parts of the lower peninsula and which is too incomplete for critical study, it seems probable that there are still in the southern part of the state a large number of unnamed species, and when these are all known it will not be surprising if the flora of Michigan is found to contain a much larger number of species than are now described.

The collection of Cratægus presents no practical difficulty, but it requires care and patience if the material is to be really useful for study. As plants of the same species often appear so different in the spring and autumn, it is necessary to mark with a number written on a parchment label or cut in the bark, each plant from which specimens are taken, so that there can be no mistake in securing flowering and fruiting specimens from the same individual. When the flowers are gathered the stamens and styles should be counted and the average number in several flowers recorded in the field note book. The average diameter of the expanded flowers should also be recorded, and special care should be taken to note carefully the color of the anthers, that is, whether dark or light rose color, pink or pale yellow. The color of the anthers is important as furnishing a good character for the determination of species. This soon fades and it is entirely lost in drying. The color in some species changes even before the flowers fade, and the safest way is to take notes on the color of the anthers before the petals expand. The autumn specimens should be gathered when the fruit is ripe or nearly ripe. Specimens gathered in summer with only partly grown fruit are absolutely worthless for the determination of species, and time spent in preparing such specimens is wasted except that they may record the existence of plants needing further investigation.

When the fruiting specimen is collected, the shape, size (length and diameter), and the color of the fruit should be noted, and whether it is pruinose or not. Notes should be made also on the color of the flesh and on its character, whether succulent, dry or juicy, sweet or bitter. The field notes should give the date when the flowers and fruits are gathered; the size and

habit of the plant, the character of the bark and the absence or presence of spines on the stems and large branches, the nature of the soil and situation where the plant grows, its abundance and such other information as cannot be obtained by the examination of the herbarium specimen. If these simple rules are followed there is no difficulty in preparing specimens that can be used for the determination of species and the description of new ones, and the Academy, through its members living in different parts of the state, can by organizing a systematic study of this interesting genus, make an important contribution to the knowledge of the North American flora.

Following this introduction is a systematic treatment of the species described, accompanied by keys for the identification both of the sub-genera and of the species.

Jamaica Plain, Mass.

SOME INTERESTING GLACIAL PHENOMENA IN THE MARQUETTE REGION.

CHARLES A. DAVIS.

(By permission of Alfred C. Lane, State Geologist.)

ABSTRACT.

(A full account will be published in a forthcoming report of the Michigan Geol. Survey.)

During the field season of 1906 the writer was assigned by the State Geologist, Dr. A. C. Lane, the work of completing the soil survey of the Northern Peninsula of Michigan, begun two years before by Professor I. C. Russell, and continued by him and Mr. Frank Leverett of the U. S. G. S. during 1905. In addition to the soil survey, attention was given to mapping the glacial features and to other surface phenomena, and it is to some of the glacial records and their interpretation that attention is called by this paper.

The region unmapped lay to the west of a line south from Marquette and north of the south line of Tp. 43 N., and amounted to more than 200 townships, or, in round numbers, 7500 square miles, much of it in nearly primitive condition without roads or settlements except along the railroad lines, hence it is a difficult area to study in detail. The portion of this territory to which attention is called lies in Marquette and Baraga counties, and in this the following phenomena were noted and conclusions deduced:

(1) Very light glaciation, especially light erosion, in all parts of the area, and practically none in the high parts of the Laurentian highland in the north half of Marquette county above 1800 feet a. t. In the vicinity of Marquette there are excellent examples of glacial erosion imposed upon pre- or inter-glacial weathering, without erasing it, while in the highlands north of Michigamme, and both east and west of that point, recently uncovered rock surfaces show no glacial smoothing or erosion.

(2) On the north side of the Laurentian highland are three or four great morainal terraces, made up of moraines and their accompanying outwash plains. The latter rise quite to the level of the tops of the moraines, filling in the space between the rock highland and moraines and giving the terrace form to the whole deposit. Above these, on the ancient rock peneplain the till deposits are practically all in the form of valley moraines of very small extent, or are wanting, while rock hills and valleys constitute the chief topographic features. The valleys contain gravel deposits or are partly filled with great deposits of uneroded talus from the cliffs.

(3) The south side of the highland westward from just west of Ishpeming, along the D. S. S. and A. R. R., is marked by high, often precipitous cliffs, banked against which is generally a thin deposit of till, covering, in some cases at least, talus material. From this low bank, extending always southeastward, branch off a number of low moraines, which in places are so covered by forests and so closely related to lines of rock hills that it is often

hard to trace them for any distance. As one proceeds westward there is a series of moraines to the south of the highland, which trend almost east and west, nearly parallel with its southern border, which are stronger than the one mentioned above.

(4) The series of terraces lying along the north side of the highland extends westward to the valley of the Sturgeon river, where the highland practically ends, and from thence westward they are replaced by a heavy moraine with terraces on the north side, which apparently is continuous with the moraines lying against the Copper Range, forming the back-bone of the Keweenaw Peninsula. The till in this deposit is red, clayey, with numerous red sandstone fragments, etc., while that of the lower ridges on the south side of it, is gray and sandy with an abundance of slates and some little granite.

(5) The glacial drainage is well marked and significant. The main lines of drainage when the ice was at its highest, after the highland became bare, were southward across the highland, through the rock valleys in which the Peshekeme river and its tributaries now run, and then east along the edge of the highland, and then southeast. The best defined of the channels for this position of the ice, was one which ran in the shallow valley now occupied by the west branch of the Escanaba river, but at earlier stages the water seems to have been forced against the cliffs much farther east, and may have flowed even as far as Negaunee before finding an outlet to the south.

A second line of drainage at this time, or a little later, was in the valley now occupied by the head-waters of the Sturgeon, near Nestoria. There was a strong stream from this outlet, following the edge of the highland eastward for several miles, which formed a sand-plain of considerable size at Three Lakes, and then probably at one time entered the Michigamme basin, and later, flowed to the southwest of it. The Peshemeke gravel plain is very extensive and contains great quantities of sandstone pebbles, which get more numerous and larger to the northward. There is no divide between the waters of the present stream flowing into Lake Michigamme and southward, and the headwaters of the Escanaba, which follow the glacial drainage lines to the southeast, and there are channels in the plain which permit the Peshekeme by a rise of four feet to flow into the Escanaba.

(6) In this whole region west and southwest of Ishpeming, there is a strong slope of the land southward, despite the southeasterly flow of the streams, which lie almost wholly in sand valleys.

(7) There are some good examples of boulders deposited to the northward of the known outcrops of the same kind of rock, but granite is the prevailing boulder material and is most widely distributed in the entire region as the bedrock.

(8) The striæ from Ishpeming west are chiefly north 75° east, and near Clarksburg, seven miles west of Isphening, is a fine example of knob-and-train structure in the form of a rock hill, which is bare on the west side, but has a till ridge extending out for several hundred feet on the northeast side, the axis of which lies N. 75° E.

(9) In the vicinity of Ishpeming and Negaunee there are a number of small valley moraines with independent outwash plains on the south sides. The glaciation, as represented by striæ and rock erosion, is light in this vicinity, as in other places.

(10) In the extensive sand-plain which lies along the valley of the Escanaba river fifteen miles southwest of Ishpeming, there is an exceedingly

broad erosion valley, more than a mile wide and with a forty foot bank on the north side, in the middle of which the present insignificant stream now runs in its own rather deep, narrow valley. There are at least two small, partly buried moraines across this sand-plain, and the plain ends abruptly on the south side in a steep descent to the south, which is boulder-covered and has all the characteristics of the ice-side of a moraine, while the north side is so level that it is difficult to see where the sand-plain ends until the edge of the southward slope is reached.

The conclusions reached from a study of these facts are:

(1) That there exists in northern Marquette county an area of several townships' extent which is almost without glaciation. This land rises to nearly or quite 2000 feet above tide in the higher parts, and is 100 or 200 feet lower in the valleys.

(2) From the fact that the drainage was across this highland and followed pre-glacial rock valleys, while the ice was piled up around its outer margin, it is evident that this area must have been early abandoned by the local ice-cap which covered it.

(3) From the position of the moraines, and the drainage lines, it seems evident that the ice lying south of the uncovered area was moving in from the west and not from the east, and while this is not yet established, it seems probable that the direct movement of the ice from the northeast was practically checked by the Marquette highland and by the Copper Range.

(4) The region to the south of this was covered by ice which pushed in on the west side of the Keweenaw Range, with a generally southeasterly movement, which spread out on the slope lying south of the highland, up to, but not over, the cliffs bounding this, and formed weak moraines as far east as Clarksburg, and possibly as far as the complicated region about Ishpeming and Negaunee, which has some characteristics of an interlobate area. This southeastward movement is indicated especially by the present stream valleys which follow lines of ice drainage diagonally across the general slope of the land, and by the fact that the clayey red till characteristic of the high moraine assumed to limit the movement of ice from the northeast, ends abruptly with this moraine, and is replaced in the adjacent lower moraines to the south of it, assumed to be formed by western ice, by gray till of a much more sandy structure.

(5) The presence of strong moraines running east and west to the south of the highland, which have drainage lines along their northern sides, indicate that the axis of movement lay to the south, and adds to the probability that the ice forming them was moving from the westward down the land-slope, rather than from the east up the slope. In the latter case it would seem as if the chief moraines would have been formed about northeast and southwest, since the thicker ice and more rapid movement would have been in the low lands to the south. In case the ice had pushed through the relatively narrow passage at the head of the Keweenaw embayment and spread out to the southeast, the main axis of movement would have been southward, and it would seem that the moraines would have been more or less concentric at right angles to this line, and the thin, more remote ones would have run northeast and southwest on the eastern side of the axis. As there is no evidence that the ice pushed in from the northeast over the Laurentian highland and much that it did not, but a word need be said regarding this possibility. In case a movement is assumed from this direction, it is impossible to explain the presence of the morainal bank against the foot of the bounding

cliff, and the marginal drainage, which evidently was on the present land surface and not in the ice.

It is apparent, therefore, that the chief contentions are, that the glacial ice from the northeast did not move across the higher parts of the Laurentian highland, but lay banked around it in a nearly stagnant condition, hence there was little glacial erosion, even on the lower slopes along the shores of Lake Superior, and practically no glaciation of any sort in the highlands, while above the highest moraines the country is nearly driftless. The same stagnation apparently prevailed in the ice-field as far west as the axis of Keweenaw point, and this ice was further prevented from penetrating inland, south of the highland, by a strong ice-stream pushing in from the northwest, on the west side of the Keweenaw peninsula.

Ann Arbor, Mich., March, 1907.

GEOLOGY AND PHYSICAL GEOGRAPHY OF MICHIGAN.

W. F. Cooper, Michigan Geological Survey.

CONTENTS.

INTRODUCTION. GEOLOGY AND PHYSICAL GEOGRAPHY DEFINED. CORRELATIONS.

Geology has been variously defined as the physical history of the earth and its inhabitants, as recorded in its structure. It includes an account of the changes through which they have passed, the laws of these changes, and their causes. In a word, it is the history of the evolution of the earth and its inhabitants[1]. In a later work we have geology defined as that science which treats "of the structure of the earth, of the various stages through which it has passed, and of the living beings that have dwelt upon it, together with the agencies and processes involved in the changes it has undergone. Geology is essentially a history of the earth and its inhabitants."[2]

On the other hand physical geography is defined as that "branch of geography that treats of the physical features of the earth, more especially those of its surface, including the operation of existing physical agencies, the distribution and flow of water, and the distribution of the forms of animal and plant life."[3] Again in this connection we have the subject of physiographic geology, "a general study of the existing features of the earth's surface, as contours of continents and systems of surface relief, partially synonymous with physical geography, but dealing with general physical features as resultants of past dynamical agencies, while physical geography deals with details, chiefly as existing under recent or present dynamical forces."[4] As treated in this paper I will combine certain phases of both subjects as given in this and the former definition, eliminating any consideration of the distribution of the forms of plant and animal life.

The principal departments of the science of geology may be divided into structural geology, historical geology or the treatment of the succession of events, while stratigraphic geology deals with the succession of beds laid

1 Joseph Le Conte, "Elements of Geology", 1896, p. 1.
2 Chamberlin & Salisbury, "Geology", Volumn I, p. 1 .
3 Standard Dictionary.
4 Standard Dictionary.

down in the progress of the ages, dynamical geology "the treatment of causes, agencies and processes."[1]

The factors embraced in the study of physical geography are mainly the atmospheric temperature, the effect of meteoric water, with the resultants of topographic forms, denudation and aggradation. As we have just seen dynamics treats of causes, agencies and processes, which therefore furnishes the nearest correlative in geological science, and it is believed that these two branches are mutually complimentary.

As a science physical geography antedates that of geology, and was formerly understood as "embracing two equally important and closely related subjects—the interior structure of the globe and its external form."[2] James Hutton "started with the grand conception that the past history of our globe must be explained by what can be seen to be happening now, or to have happened only recently. The dominant idea in his philosophy is that the present is the key to the past. The pudding stones were in his eyes only compacted gravels, the sandstones were indurated sands, the limestones were in great part derived from the accumulation of the remains of marine calcareous organisms, the shales from the consolidation of mud and silt."[3] It is with certain of these agents and resultants that we have here to deal. In this connection I am indebted to Wm. M. Davis, professor of physical geology at Harvard University, for a communication on the subject:

"I will only say in brief that I regard physical geography, or physiography, as a sub-heading of geography, and treating of all the inorganic content of geography, namely, everything concerning the earth as a globe—the oceans, the air and the lands which go to make up the inorganic environment of organic inhabitants of the earth. Geography as a whole I look upon as simply the geology of today; as I have sometimes expressed it, geography is only today's issue of a world's record, the complete files of which would constitute geology; or, in other words, geography is the top member of a series of strata horizontally arranged with respect to the vertical time line. There has always been a geography, and geology is nothing but a summation of all geographies of the past, up to and including the present. The chief reason that has separated geography from geology so long, and so much to its disadvantage is that the facts of geography are open to immediate observation as existing phenomena. The facts of past geographies, which make up geology, are determined only by inference and are known very incompletely. In their essence, however, they would surely be very much like the observable facts of today's geography. It is for this reason that the whole tendency of my work has been to bring out a closer association of geology and geography than has been customary in the past. A great deal that is taught in geology, concerning processes now going on, is good physical geography. The bulk of historical geology is (fragmentary) geography of past ages—partly physical, partly organic (ontographic.)"

"In a sense physical geography is to geology as physiology is to anatomy, the essential element being activity in its effect on geological deposits, as embodied in dynamic agencies. The agents as far as will be considered here, are the water, precipitation, the results and changes of temperature, with certain topographic features. These factors and the dynamic result-

1 Chamberlin & Salisbury, Geology, Volumn I, p. 1.
2. "The Principles of Geology", Volume I, A. Geikie, 1901, p. 74.
3 Idem. p. 168.

ants of earlier geological conditions enter largely into the relief of the surface of Michigan."[1]

"Physical geography is the geology of the present, while one branch of geology is the physical geography of the past."[2]

MICHIGAN GEOLOGICAL SURVEY.

In the reports of the Michigan Geological Survey dealing with Monroe, Sanilac, Huron and Bay counties the topics chiefly dealt with relate to climate, configuration, elevations, surface and underground drainage, shore lines, contours, elevation of the great lake basin and subordinately related subjects.

WINCHELL'S DIAGONAL SYSTEM.

Dr. Alexander Winchell in 1873 read a paper before the American Association for the Advancement of Science entitled "The Diagonal System of the Physical Features of Michigan."[3]

"The actual topographical and hydrographical axes of Michigan and the whole lake region, are the resultant of two forces—a glacial acting from the N. E. and a stratigraphical acting along the lines of strike of the rock formation. As a corollary we should find that where the rocky formations are most consolidated, the resultant lies nearest the lines of the stratigraphical force, and where the resultant approximates the line of the glacial force. As a second corollary physical features determined by causes which have obliterated the glacial and stratigraphical trends, do not, necessarily, express relations to either force. Of this kind are the small streams whose courses over the diluvial beds have been determined by post-glacial erosions, and river courses, like the St. Clair and Detroit, marked out across lacustrine or other post-glacial deposits which have concealed the surface features due to geological structure or glacial erosion."[4]

ORIGIN OF THE GREAT LAKE BASINS.

Michigan being a peninsular state the question is pertinent as to the causes which produced the basins forming the adjacent great lakes. "It is to be observed that concave tracts border the continents very generally. They are connected with the descent from the continental shelf to the abysmal basins and are unsymmetrical. Notable concavities are found in some of the great valleys on the continental platforms. The basins of Lakes Superior, Michigan and Huron are in part concave. When to the weakness of the crust, as computed under ideal conditions, there is added the weakness inherent in these concave and warped tracts, the conclusion seems imperative that while the crust is the pliant subjects of minor and nearly constant warpings, such as are everywhere implied in the stratigraphic series, it is wholly incompetent to be the medium of those great deformations which occur at long intervals and mark off the great eras of geologic history."[5] The Lake Superior basin as thus stated is an early crustal warping which antedates Paleozoic time. The basins of Lake Michigan and Huron occupy lateral parts of a considerable earth concavity existant during early Paleo-

1 Bay county, W. F. Cooper, Ann. Rep. of the Mich. Geol. Surv., 1905, p. 355.
2 A. C. Lane Mich. Geol. Surv., Vol. VII, Pt. 2, p. 31.
3 W. H. Sherzer, Monroe Co., Geol. Surv. of Mich., Vol. VII, part I, p. 118.
4 Tackabury's Atlas, A. Winchell, 1883.
5 Chamberlin & Salisbury, Geology, Volume I, pp. 558–562, 1904.

zoic time, built up by median and later succeeding formations, not unlike saucers laid upon each other, the latest bed rock formation, the Coal Measures, being at a later time relatively elevated, in conformity with the law established by James Hall of the greatest accumulation of sediment forming areas of uplift and consequent highest elevation. In this manner it can be seen that the physiography of Michigan as seen in its present development has very early geological antecedents.

AREA AND ELEVATION OF MICHIGAN. PRE-GLACIAL DRAINAGE.

According to the statement furnished by Mr. H. M. Wilson, Geographer for the U. S. Geological Survey, the area of Michigan is now accepted as 57,480 square miles. By planimeter measurement of Plate II of Water Supply Paper No. 183, issued by the government, I make the area of the Lower Peninsula 41,452 square miles. Newaygo county was taken as the unit of comparison and area. Computations based on Farmer's "Michigan Book" give an area of 16,560 square miles for the Upper Peninsula. By difference I would make this area 16,628 square miles.

Mr. Henry M. Gannett has issued the fourth edition of his Dictionary of Altitudes, this publication being Bulletin No. 274 issued by the U. S. Geological Survey. An average of 1457 altitudes, the greater part being railroad stations, determined with as much accuracy as possible, gives Michigan an average elevation of 840 feet above sea level. Lake Erie is 572 feet above tide and lake Superior 602 feet above the level of the sea. This determination is very likely somewhat below the true elevation, but is based upon the only complete information at present available.

The average elevation of the Lower Peninsula of Michigan is 854 feet above sea level as determined from a 100-foot surface contour map prepared by Frank Leverett and forming Plate II of Water-Supply Paper 183, issued by the U. S. Geological Survey. In making this determination "the first step was to measure, by means of the planimeter, the areas lying between different contours. Then each such area may be assigned an elevation half way between the two limiting contours, and multiplied by that number of feet. The sum of these products divided by the area give an approximation of the average height."[1]

The percentage of area in Lower Michigan between the different contours is shown in the following table:

600– 700	feet	above	sea	level	= 23%
700– 800	"	"	"	"	26
800– 900	"	"	"	"	21
900–1000	"	"	"	"	14
1000–1100	"	"	"	"	6
1100–1200	"	"	"	"	8
1200–1300	"	"	"	"	2
1300–1400	"	"	"	"	.03
1400–1710	"	"	"	"	.002

The line of 44° latitude extends from just north of Standish, Arenac county, west to just north of Ludington on the Lake Michigan shore and includes in latitude the northern 5–12 of the state. Within this area is the highest elevation in Lower Michigan. The following percentages apply to this area:

1 Communication, Henry Gannett, Feb. 8, 1907.

600– 700 feet above sea level =	24.2%
700– 800 " " " "	15.
800– 900 " " " "	12.
900–1000 " " " "	9.
1000–1100 " " " "	8.
1100–1200 " " " "	25.
1200–1300 " " " "	6.
1300–1400 " " " "	.08
1400–1710 " " " "	.006

The most remarkable feature indicated by this table is the plateau formation above the 1100-foot contour line which embraces the greatest part of the upper portion of the Lower Peninsula.

The average elevation for bed rock of Lower Michigan as determined from Plate II of the report referred to above is 554 feet above sea level, making the average thickness of the soil and subsoil formation, properly known as the drift, approximately 300 feet for Lower Michigan. There is considerable margin for error here, but all knowledge is progressive and beginnings are to be taken in the proper spirit. In Bay county we have an average thickness of the drift of 97 feet as determined from 460 drill holes for coal and 126 well records.[1]

Probably the highest elevation in Upper Michigan is Mt. Whitney in the Porcupine Mountains, and not far from Ontonagon, which has a height of 2023 feet above sea level, and this is probably the highest altitude in the state.

In the Lower Peninsula we have two areas of topographic development, which are clearly the result of former geological conditions. In the central part of the state we have the Saginaw-Maple-Grand valley. South of this in the Hillsdale uplands we have the highest elevation south of the latitude of Saginaw Bay, this portion of the state culminating at Bunday Hill, where the elevation is 1284 feet above tide. North of this area, southeast of Cadillac, and in the north central part of Osceola county, the land reaches an altitude of 1710 feet above sea level, which I am told is the highest elevation in Lower Michigan. It is, moreover, worthy of note that both the elevation of the bed rock and the present land surface vary approximately 1100 feet in extremes of elevation in this portion of Michigan, indicating a certain amount of uniformity in topographic developments and the resultants of agencies during glacial and earlier geological periods.

In the report on the "Geology of Bay County," the former drainage system of the state, which was in the course of development after the elevation of Michigan above the sea at about the close of the Paleozoic, was given specific designations in the same manner that our present drainage system is designated.[2] The advantage of this plan is in convenience and definiteness of arrangement and designation, while on the other hand we are able to reconstruct the former physical geography of the Lower Peninsula, in a manner consistent with the present, thereby giving life and unity to long bygone times.

During this former age of topographic development during Mesozoic and Cenozoic times the drainage in central Michigan was westward, probably through the southern part of Bay and Midland counties, the northern part

1 W. F. Cooper, Bay Co., Ann. Rep. Geol. Surv. of Mich. for 1905, p. 339.
2 Geology, Bay Co., Ann. Rep. Mich. Geol. Surv., 1905, pp. 162–165 and 333–339.

of Gratiot and Montcalm and thence northwestward towards Manistee and Ludington where the former drainage was not far from sea level, there being a drop of not less than 400 feet in its course westward from Saginaw Bay. I would suggest the name of Alma channel for this former drainage course as the upper reaches of this channel passes underneath that town where the depth has been obtained. It will be observed that this former drainage channel is more or less parallel and just north of the present Saginaw-Maple river valley, and a portion of the Grand river to which the Maple is tributary. It seems not impossible that the very large amount of glacial debris which would be required to fill the former Alma channel resulted in a lack of material further south, the result being the depression forming the present area of the Saginaw-Maple-Grand valley, across which a ship canal was at one time projected. The present depressed topographic feature was also very likely considerably lowered during the lacustrine period toward the close of the Pleistocene, when the drainage of a portion of the former glacial lake series had an outlet near Pewamo and thence drained westward into the basin of the Grand river. In Bay county we have coming into this Alma channel the Beaver, Auburn, Amelith and Souwestconning channels, all the drainage being westward and southwestward. They have there been designated washouts in deference to the usage among the miners, which is moreover appropriate and perhaps worthy of continuance, but on the other hand it is well to have all the unity compatable with scientific accuracy. Within the 400-foot above tide rock contour line the Alma channel has an area of about 2,751 square miles and an average depth of 162 feet. To this, however, should perhaps be added a depth of 300 feet for erosion during the glacial period, which figure represents the possible average depth of glacial and glacio-fluvial deposits and therefore since a greater part of the glacial drift, soils and subsoils, was probably only carried a comparatively short distance, the amount of erosion in the peneplain through which the Alma channel worked its way. Consequently we have an average depth of 462 feet if not more for this buried channel in its theoretical restoration.

This does not, however, take into account a certain amount of erosion of the Alma basin during Mesozoic and Cenozoic times, beyond the limits of the apparent valley, and I do not know of any way in which this amount of erosion can be determined. Since very nearly all streams have their outlets either into lakes, gulfs, seas or oceans, it is necessary to infer that the Alma channel either emptied its burden of sediment into a former lake in the area occupied by at least a portion of the present body of Lake Michigan, or on the other hand the channel may have been continued onward. Since stream development is both progressively downward in cutting its channel, and also away from its outlet by head erosion it is necessary to add to the approximate vertical depth near its apparent outlet above Ludington, a later development of this same channel as in its upper reaches near Bay county As near as I can calculate this would give an erosive record of some 400 feet to which will be added 300 feet of erosion as represented by the record obliterated during the glacial period. This entire estimate is at least a portion of the erosion which took place during Mesozoic and Cenozoic times. This combined record, therefore, may represent a vertical equivalent of 700 feet.

PRE-GLACIAL RAINFALL.

My object in going into some detail regarding the Alma channel is to gather such information as is obtainable concerning the amount of rainfall subsequent to Paleozoic time and antecedent to the glacial epoch when beds of soils and subsoils were in process of formation. That precipitation took place at very early geological times is indicated by the beds of glacial deposits formed during Cambrian time at the base of the Paleozoic formation and in Permian beds at the close of the Paleozoic. Only recently Mr. A. P. Coleman has described in the March number of the "American Journal of Science" boulder bearing rocks in the Huronian formation of Canada which may represent glacial deposits of very early age.

Calculating as nearly as possible the amount of rock removed by erosion in the Alma channel, the amount of water which is necessary to remove a cubic foot of rock material, the relation of rainfall to run-off by means of which erosion was accomplished, the relative area in which precipitation and active erosion took place, and the uncertain duration of time during which erosion was acting, we have the factors by means of which the amount of annual rainfall may be uncertainly estimated during the period subsequent to the elevation of Lower Michigan above the sea at about the close of the Paleozoic and previous to the glacial epoch. Without going into all the calculations the result arrived at amounted to about 29 or 30 inches annually for one square mile for Mesozoic and Cenozoic times. I believe that the present amount of rainfall is given as 32 inches for Lower Michigan. The factors used are: 2611 cubic feet of water is required to remove one cubic foot of sediment over a drainage-erosion area of 1,244,000 square miles or less; 16,355,339,000 cubic feet of sediment in one square mile 700 feet deep; the runoff varies to the rainfall as from 33 to 56%, the average of 12 streams being 46%; the period of time is 2,450,000 years, more or less. The most uncertain factors in this calculation are the amount of rock removed by erosion, the relation of rainfall to run-off at that time, the duration of time, and the relation of active erosion to the entire basin of the Mississippi, which is one of the essential elements in this calculation. This last subject is worthy of additional investigation on the part of physical geographers and geologists. While these speculations might arouse the envy of the amalgamated nerve of E. H. Harriman and a certain proportion of the Wall Street organization of metaphorical quadrapeds I trust that it will lead to further investigations and results that will give material for comparison and more accurate information.

TILTING OF THE GREAT LAKE BASINS, SHORE LINES, WILLOWY DRAINAGE.

This subject of tilting of the Great Lake basin was first discussed by G. K. Gilbert in the 18th annual report of the U. S. Geological Survey, the result being that if a line is drawn N. 10° E., 100 miles long, that at the end of 100 years the north end of this line would rise .4 of a foot relative to the south end. The nodal line of stability is calculated to pass from Port Huron to Saginaw and thence northwest towards Manistee, the land rising to the north of that line and sinking towards the south. For further information of the details of this interesting subject the reader is referred to the reports on the geology of Huron and Bay counties of the Michigan Geological Survey.

The south shore of Lake Superior is apparently sinking in the Porcupines.

It is an obvious corollary from this, that the river valleys would have

comparatively rapid descents into Lakes Michigan and Huron above the places named, while to the south of this diagonal line the outlets of river valleys would be drowned. Thus we have along the south shore of Lake Michigan what might be termed river-lakes at the outlets of the Grand, Muskegon and Marquette rivers, where these river reaches have been drowned by relative sinking and encroachment of the lake. Further northward stream channels have a relatively rapid descent into the lake.

The cause and effect of glacial-geologic action and resultant drainage, has in many cases produced a striking form of drainage.[1] In the Saginaw Bay basin the Tittabawassee and Cass rivers are deflected by the Saginaw-Port Huron moraine toward the south until meeting in the Saginaw river, the concave area opening to the north. This type of river flow has very appropriately been styled willowy drainage, in this case the Saginaw river forming the trunk of the tree, the Cass and Tittabawassee lateral branches. On the west coast the St. Joseph river forms a bow into northern Indiana. There are, however, numerous streams which follow a more direct course, the simplest type is where there is a smooth even sloping plain, the water courses following nearly parallel and independent drainage lines, as in Bay county.[2] However, in the same county we have this willowy type of drainage characteristically developed. It is also characteristic of this type of drainage that the main tributary streams come in from the south of the trunk stream. In Bay county this is at least due to the more abrupt descent of the front of the moraine last deserted.

TERRACES.

These originate in various ways.

1. Due to inequalities of hardness, the upper surface of the hard layer marks the lower limit of the terrace.

2. Due to flood plain deposition along the sides of a stream, and subsequent down cutting of the channels by various operations as follows:

a. The head advancing up stream may on reaching the head of the valley plain lose so much of its load as to be able to sink its channel farther down, forming cycles of erosion with alternate deposition, cutting and deposition again.

b. By the exchange of load dropping the course near the head of its valley plain and taking up fine material, thus degrading its channel into the flood-plain which the earlier and perhaps smaller stream had developed.

c. As erosion and transportation vary accordingly to the grade of the stream the flood-plain may be subsequently deepened due to stream development which permits material to be removed which is temporarily left on the flood plain.

d. Any stream reaching the flood plain stage is apt to meander, the meanders tend to migrate down stream and become relatively lower and more capacious so as to hold the water of ordinary floods. At this stage or even before, such parts of the earlier flood plain as remain are terraces. Other causes are the uplifts in a region where the rivers are flats, the streams are rejuvenated, and the remnants of their former flood plains become terraces. Again if an alluvial flood plain has been built as the result of excessive sediment, the exhaustion or withdrawal of the excessive supply would leave the stream free to erode it where it had been depositing. An increase in

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1 A. C. Lane, Water-Supply Paper No. 30, U. S. G. S., p. 62.
2 W. F. Cooper, Bay Co., Ann. Rep. Mich. Goel. Surv. for 1905, p. 373.

the volume of a stream, without increasing its load, as by stream capture may occasion the development of terraces by allowing the stream to deepen its channel. Barriers may cause flood plains, their removal will cause the stream to cut more or less deeply into the plain above, leaving terraces. The recession of a falls through a floodplain convert such parts of it as remain, into terraces.[1] Prof. I. C. Russell has described terrace formation lateral to the Menominee river by cutting down through broad alluvial plains, the highest terrace being the plain itself, the lower terraces were eroded in subsequent flood plains. Again he describes terrace formations adjacent to Green Bay which are due to subsequent lowering of the lake and down cutting of the stream channel.[2]

TEMPERATURE.

Finally I would like to be permitted to digress a minute and call attention to the very favorable opportunity of studying the effect of water temperatures on the insular climate of Lower Michigan. The prevailing wind in Lower Michigan is from the southwest, so that members of the Academy living on the Lake Michigan shore can have an opportunity of determining the results and relationship of the exact effect of water temperature on that of the land. An average of the isothermal lines shows the same temperature averages extending 46 miles farther northward on the west side of the Lower Peninsula as compared to the east side. Comparing the results on the east and west sides of Lake Michigan we have an average of 36 miles farther north than on the east coast of Wisconsin in crossing the lake. During the latter part of August the average water temperature is about 4° greater than that of the air. Also during this time the ratio of change of water temperature relative to that of the air temperature is less than 34.4%. In this factor taking into account the prevailing southwesterly winds, we find a partial explanation of the insular climate of Lower Michigan. Moreover the temperature of the water, as a rule, being greater than that of the air from about 7 p. m. until about 9 a. m. the following day, the tendency would be to increase the temperature of the adjacent windward shores. On the other hand, the air temperature being greater during the remainder of the day, the water would tend to establish an equilibrium by reducing the air temperature the mean range probably approaching the mean of the average ranges of air and water temperatures. The more prolonged period of average higher water temperature is doubtless the greater factor in this question.[3]

Observations of this character to be of general value should be taken at least once a week throughout the year and should be continuous for 24 hours, readings being taken every hour beginning at say 6 p. m. Readings of the air temperature on the land and of the surface water temperature at the end of a pier where there is 15–20 feet of water should be taken as nearly together as possible. As to the proper way in which this work can be carried on information from C. F. Schneider, head of the State Weather Bureau, at Grand Rapids could be obtained, and perhaps the use of an accurate thermometer suitable for the purpose. The results would be of very considerable scientific value.

Lansing, Michigan, March 26, 1907.

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1 Chamberlin & Salisbury, Geology, Vol. I, p. 193–198.
2 I. C. Russell, Ann. Rep. Mich. Geol. Surv., 1906, pp. 77–78.
3 Michigan Academy of Science, 7th annual report, p. 40–43, and Monthly Weather Review, Washington, D. C., Dec. 1905.

FORMALDEHYDE DISINFECTION BY MEANS OF POTASSIUM PERMANGANATE.

E. M. HOUGHTON, L. T. CLARK.

Formaldehyde has been recognized for several years as the most efficient germicide available for disinfecting closed rooms and apartments. Some difficulty has been encountered in devising a safe, economical, and equally effective method for liberating the gas from its liquid or solid state, that would do away with the necessity for expensive apparatus and an experienced operator.

Various means have been employed for liberating the gas from saturated aqueous solutions of formaldehyde and from its dry polymeric form, paraform. The following methods have been the most extensively used: autoclave under pressure; retort without pressure; generator or lamp; formaldehyde and dry heat in partial vacuum; sheet spraying; and heating paraform. These several ways have had their respective good qualities as well as their objectionable features. The autoclave under pressure and retort without pressure are perpaps the most commonly used and rank among the first in efficiency, but they also have serious deficiencies, requiring (1) an expensive apparatus, (2) outside heat, (3) an experienced operator.

In January, 1904, Dr. G. F. Johnson, of Sioux City, Iowa, read a paper at a meeting of the Sioux Valley Medical Association, in which he described a new means for liberating formaldehyde from its solution for purposes of disinfection. This method, conveniently called "the formalin-permanganate method," differs from others quite materially, as no outside heat is required. It consists in adding potassium permanganate crystals to full-strength formaldehyde solution in a convenient receptacle placed in the center of the room to be disinfected. Various proportions of permanganate and formaldehyde have been employed, but McClintic, of the Department of Public Health and Marine Hospital Service, as the result of an elaborate series of experiments, has recently reported that the best results are obtained when fifty grams of potassium permanganate are brought in contact with one hundred cubic centimeters of formaldehyde, or multiples of these quantities, depending upon the space to be disinfected. Within a few seconds to one minute, depending upon the size of crystals used and the temperature of the room, a vigorous reaction ensues, causing strong ebullition of the liquid and producing sufficient heat to liberate a large volume of formaldehyde gas and water vapor. This boiling continues from four to six minutes, becomes less vigorous, and gradually recedes until nothing remains except the nearly dry residue. In many of our trials it became thoroughly dry. In the majority of cases, however, this residue consisted of a lower grade of manganese, a very small amount of formaldehyde, carbon dioxide, potassium hydrate and some moisture. According to McClintic the liberation of the gas and water vapor is brought about according to the following reaction: $-4\ K\ MnO4 + 3\ HCOH + H2O = 4MnO\ (OH)2 + 2\ K\ 2CO3 + CO2\ (CO2)$, the heat produced causing the liberation of formaldehyde and water vapor. Contrary to the general belief, the amount of

formaldehyde destroyed is very small, as McClintic showed that the amount of gas in his test rooms was substantially the same as where an equivalent amount of the disinfectant was liberated by the autoclave, etc.

The following figures obtained from some of our experiments and from Dr. McClintic's results will convey a good idea of the exact amount of formaldehyde absorbed in the reaction and that liberated as gas. Computing from Dr. McClintic's formula, we find the amount of formaldehyde necessary to cause a complete reaction in the permanganate taken by using the following equation

4 $KMnO_4$: 3 HC OH :: weight of permanganate used : X, or 628 : 90 :: 240 : X.

X = 34 grms. formaldehyde used, that is, 85 Cc of the formaldehyde would be used in the reaction, and the remainder, 395 Cc, would be driven off into the room.

To verify these results we made trial experiments and weighed the material before and after the reaction.

Weight of formaldehyde	510	grams.
Weight of pail	992	"
Weight of briquettes	281	"
Total	1783	"
Weight of pail and residue after reaction	1432	"
Loss during reaction	351	"
Weight of moisture in residue	43	"
Loss and moisture	394	"

Thus accounting for all but 1 gram of material that would be driven off, as shown by Dr. McClintic's formula.

Practically it is found that in the ordinary commercial 40% formaldehyde solution 38% is available by the autoclave method, while with this method we can expect 33⅓%, which does not differ greatly from the other, and even this apparent advantage in the autoclave method is more than counterbalanced by the very rapid liberation of the gas, which makes for very thorough disinfection the end sought by sanitarians.

The public is becoming more thoroughly enlightened as to the necessity of disinfection, and Health Boards are demanding that the most efficient sanitary precautions shall be taken to limit the spread of the infectious diseases. Nothing has been discovered that will satisfactorily take the place of formaldehyde, hence there is a crying demand for a more simple, practical and efficient means of rendering the disinfectant available, and the formalin-permanganate method should win a place for itself.

Some preliminary experiments, carried out to determine the merits o, demerits of this new method as applied to disinfection in a practical wayr verified the results obtained by the department of Public Health and Marine Hospital Service in their experiments to determine the best means of disinfecting railroad coaches. During the progress of our experiments it was found that, when potassium permanganate crystals were added to formaldehyde in the above named proportions, in quantities sufficient to disinfect the ordinary sized living room, very violent ebullition and foaming occurred, causing the material to boil over sides of receptacle. In our trials 240 grams of potassium permanganate crystals were placed in an

ordinary three-gallon pail and 480 Cc, one pint, of 40% formaldehyde was poured upon them, these quantities being sufficient to disinfect 1600 cu. ft. of space.

As the spattering and foaming over the rim of pail caused by such very violent ebullition were, to say the least, very objectionable, measures were adopted to retard the reaction sufficiently to avoid this difficulty. After trying several series of experiments, the desired result was successfully accomplished by incorporating with the potassium permanganate crystals 15% Portland cement and enough water to give the mixture the proper consistency for compressing into small briquettes. After compression, these briquettes are left until dry, when they can be readily handled.

With the potassium permanganate crystals in this compact form, the method becomes very simple and easy of operation. The charge, 480 Cc of formaldehyde, is poured into a three-gallon metal pail, and the three briquettes containing 240 grams of potassium permanganate crystals are quickly dropped into the liquid. The reaction ensues more slowly and with less violence than when the crystals alone are used, and is not accompanied by any undesirable foaming or spattering.

In conclusion we believe the following summary may be made:

1. Formaldehyde disinfection is simply and quickly accomplished by means of the permanganate briquettes.

2. No expensive apparatus is necessary, and no outside heat is employed, thus lessening the danger of fire.

3. More thorough disinfection is accomplished, because the whole volume of gas and moisture is liberated during a very short time.

Detroit, Mich.

PROTECTIVE AND CURATIVE ARTIFICIAL IMMUNITY AS BASED ON THE THEORY OF OPSONINS.

A. P. Ohlmacher, M. D.

Artificial immunity, especially the protective immunity induced by the use of bacterial products, is a subject of practical concern to sanitarians. Artificial immunity extended to the conquest of already existing disease is likewise a topic of timely interest to sanitarians, and to mankind in general. With your permission I shall therefore discuss briefly a recent and most promising phase of immunology as applied both to the prevention and treatment of diseases caused by pathogenic microparasites, and in doing this I shall request the privilege of waiving as far as possible the very involved theoretic controversies in which recent immunology has become involved and bring you at once to the comparatively simple hypothesis underlying the work of Sir A. E. Wright and his associates which, even at this relatively early day in its development, promises advantages of momentous importance. I refer to Wright's method of bacterial inoculation, either protective or curative, as founded on the theory of opsonins, which, after a period of latency most unusual in these days of ready publicity, has abruptly sprung into very great prominence in the English speaking medical world.

The expression "founded on" the theory of opsonins must, however, be somewhat qualified, for it is a fact that Wright's early work in bacterial inoculation by which the basis for his present practice was established, was successfully prosecuted before Wright and Douglas demonstrated the existence of so-called "opsonin" in the blood serum. And this preliminary work was in the line of protective artificial immunity, the problem being the successful production of immunity against typhoid fever with which Wright in his position as pathologist to the Army Medical School at Netley laboriously engaged himself. These anti-typhoid inoculations, or as they are miscalled "vaccinations," were performed along lines already laid down with more or less success by Haffkine in his anti-cholera and anti-plague inoculations, and while considerably modified in method, rested on the precedents established in protective vaccination against smallpox, hydrophobia, anthrax, rinderpest, bovine pleuro-pneumonia and several other diseases. The particular point in the procedure on which Wright laid stress, and which has characterized his later technique, was the use of dead bacterial suspensions as the source of his inoculating medium, the vitality of the typhoid bacilli being destroyed by heating one hour at 60°C, which was effective in attaining the end sought and still did not, apparently, destroy those bacterial substances which were required to produce the desired effect. Today this procedure is generally in vogue in the preparation of the various bacterial inoculations required in treating infectious diseases according to the method of opsonic therapy.

Studying the effect of his anti-typhoid inoculations Wright at first attempted to gage these by using the agglutination test and for a time it appeared that reliance might be placed on the results. Not finding these satisfactory he next resorted to a method of measurement based on the bactericidal property of the serum of inoculated individuals. After perfecting a

technic for determining the bactericidal action of blood serum, this method of testing the blood's power, too, was abandoned and the opsonic index substituted.

As to the future of artificial imunity induced by bacterial inoculation Wright has recently delivered a remarkable forecast. Up to the present, he said, the community has devoted most of its energy to trying to kill bacteria outside the organism by hygiene and disinfection; but disease germs still lie in wait in countless millions in our food and in the air we breathe; like the poor, they will always be with us. The next advance in sanitary science will be to fight the disease within the organism, either by fortifying it in advance of infection, or before the infection has attained dangerous headway. The physician of the future must be an "immunizator."

THEORY OF OPSONINS.

Brought to its simplest terms Wright's theory of opsonins holds that an individual's blood serum contains, among other protective substances, one, opsonin, which acts directly upon pathogenic bacteria in such a manner as to prepare them for destruction by the protective body cells or phagocytes. Opsonins are assumed to be specific, as for example, one for the pyogenic staphylococci, for the streptococcus, the tubercle bacillus, and so on. When present in normal amount and when the free circulation of the serum containing opsonin is in no way impeded, pathogenic bacteria fail to excite morbid effects. But with a lowering of the blood serum's opsonic power against a given bacterium or through failure of the serum to reach a certain focus, the characteristic disease of that particular bacterium may occur because of the inability of the phagocyte to envelop and destroy it, this failure arising from no lessened activity or power of the phagocyte itself, but because the opsonin does not act upon the bacterium with sufficient energy to prepare it for destruction by the protective body cell.

By mixing, in glass, under laboratory conditions, human leucocyets washed free from serum, an emulsion of a certain bacterium, and the blood serum to be tested, according to directions which Wright and his followers have freely published in the medical periodicals of Great Britain, one may evaluate the opsonic power of that particular serum against that particular germ. For the leucocyte, washed free from serum, will not actively ingest the bacteria; and the number of bacteria taken up in a given number of leucocytes in the presence of a certain serum indicates a measure of the opsonic value of the serum under obervation. The capacity of a serum to produce phagocytosis is spoken of as its "*phagocytic index*," and a comparison of the phagocytic index of the serum with another or several from presumably normal individuals, gives the so-called "*opsonic index*." It is the determination of the opsonic index that forms the basis upon which Wright gets his indication for treatment and, in the course of treatment, graduates the dose of the bacterial virus and its repetition.

It has been found that in case of a low opsonic index against a pathogenic bacterium, particularly one belonging to the group of pus producers, the index can be raised by the subcutaneous injection of a relatively small dose of the corresponding germ; and not only does the opsonic index as ascertained in the laboratory test rise, but the increased resistance against that germ is generally shown by a condition of general well being and an improvement in whatever local lesion the microbe may have caused. Repeated at proper intervals and in correct doses this preparation of the corresponding

germ is capable of effecting recovery from the subacute or chronic infection induced by it. To these bacterial preparations which consist essentially of the suspended bodies of the microorganisms, heated just sufficiently to insure their death, and preserved with a chemical germicide like lysol, Wright has given the name "vaccine," which seems to me an unfortunate term; and in its stead I have proposed the adoption of the word "*opsonogen*"—that which forms or generates opsonin. Let us then understand that the opsonogen of opsonic therapy is a small dose of an ascertained number of dead bacteria; the microbe being a "corresponding" one, that is, identical in species with the one producing the infectious condition under treatment; or better still, the "*autogenous*" one, as I have chosen to call it, obtained directly from the patient's lesion, and reintroduced for curative purposes.

Daily tests of the opsonic index following the injection of a bacterial opsonogen show that at first there is a falling in opsonic power of the blood serum, this being named the "*negative phase*" by Wright; which is succeeded, after an interval of hours or several days, with an increased opsonic index constituting the "*positive phase.*" A practical rule of apparently prime importance is not to reinoculate during the negative phase, and preferably only when the index is again tending downward after the positive phase. Clinically one can recognize these fluctuations in opsonic power by the constitutional depression in the negative phase, often with an aggravation of the lesion, and the increased tone of the positive phase with betterment of the local condition. By repeating the proper dose of bacterial opsonogen at the right intervals (averaging 7 to 10 days) a successful result witnesses a progressive rise of the opsonic index to a maximum and sustained point, and with this a restoration of the patient.

The list of diseases amenable to artificial curative immunity as produced by bacterial inoculation is a long one. It includes such staphylococcic skin affections as acne, furunculosis, sycosis, and in my own experience I have been able to add seborrhoeic dermatitis and eczema; pneumococcic infections like empyema, cystitis, suppuration of the antrum; colon bacillus infections such as cystitis, pyelitis, pyelo-nephritis, and unhealed post-operative fistulas; gonococcic infections like acute, subacute and chronic gonorrhoea, gonorrheal rheumatism, gonorrheal epididymitis, ophthalmia and conjunctivitis; tuberculous diseases such as lupus, arthritis, cystitis and nephritis, epididymitis, adenitis, laryngitis, iritis, and some cases of pulmonary tuberculosis. Lately the method has been successfully applied in vegetative endocarditis, and in some cases of typhoid fever. It requires no great stretch of imagination to conjure a much more extended list of morbid medical and surgical affections which are embraced in the prospective field of opsonic therapy, and if present promises hold good it is not too much to predict that Wright's discoveries have opened a new territory of therapeutic conquest for microbic diseases more extensive in its scope than that of any single advance in the science of and art of medicine.

PERSONAL CLINICAL EXPERIENCE.

As to what may be accomplished in applying the practice of bacterial therapy as based on the theory of opsonins, I can perhaps best illustrate by briefly reviewing some cases that I have personally treated since last midsummer and which will serve as types of the various groups. This review must necessarily be condensed and only the sailent features of the various cases can be touched upon. And further, since I have already re-

ported a number of my cases I shall now select some of the more recent ones.

SKIN DISEASES.

Acne.—My experience in treating acne by bacterial inoculation duplicates that reported by Wright and his associates. As a rule I have employed as a source for the inoculating virus the organism (generally *Staphylococcus albus*) secured from the patient's pustular lesions or from a comedone. Of the opsonogen prepared from these autogenous cultures a dose of 200 to 500 millions is employed, the intervals between inoculations varying from 5 to 15 days depending on the opsonic index, or on the constitutional or local symptoms. In no case that I have thus far treated has benefit failed to follow, and apparently full recovery has been achieved in a number of the earlier ones. That the increasing of the blood's resistance the offending organism in any staphylococcic disease by the use of a specific opsonogen exerts a profound influence is shown by the most interesting phenomena. Thus the comedones in seborrhoeic acne are spontanoeusly extruded from the skin especially during the first three days after inoculation, until all of these unsightly blemishes disappear. That rough condition of the skin known to dermatologists as keratosis pilaris (Brocq and Unna) disappears. An oily skin becomes less oily. A dry, harsh skin becomes smooth, soft and pliable. A muddy complexion clears. If the hair is excessively oily and full of dandruff at the outset of treatment it becomes less oily and the dandruff disappears. On the other hand, dry, harsh hair on a scalp with dry, scaly dandruff, gives way to soft hair with natural oil and freedom from dandruff. I have observed the falling of hair to cease and improved growth to take place during treatment. Coincidentally there is a gain in general tone, appetite and spirits, and patients usually increase in weight. Clearly all this gives us new light upon what our forefathers were wont to call "impure blood;" and it seems that a low blood resistance against the staphylococci of the skin is responsible for more far-reaching local and constitutional conditions than the acne, seborrhoea, or other lesion, which is only the most obvious in its manifestations; and further, that by augmenting the blood's power, or as we have it in lay parlance, to "purify the blood," by the use of these wonderfully subtle and potent bacterial inoculations, we remedy all the defects. At this juncture I might also add that analogous widespread effects follow the use of other proper and specific inoculations as when directed against the diseases caused by the streptococci, the pneumococci, the colon bacilli, the tubercle bacilli, and the gonococci.

Furunculosis.—My first patient with boils was my two-year-old baby girl in whom a staphylococcus infection of mosquito bites on its scalp produced a series of large pustules, one after another of which I incised until the procedure became a severe trial to both the patient and myself. For six weeks these boils continued to appear on the scalp and when I finally concluded to use the opsonogen which had been prepared from the staphylococcus aureus isolated from one of the early furuncles, one large boil was present on the side of the head, two on the abdomen in sites not previously the seat of mosquito bites, and one very large so-called "blind boil" on the pudendum. All these were incised and the first and only inoculation made. From that day last midsummer to the present the child has had no sigh of a furuncle. This satisfactory experience I have since repeated in a number of cases of subacute or chronic boils and in one case of carbuncle.

Furunculosis and Axillary Adenitis.—Another of my early staphylococcus

cases was one in which a boil appeared on the anterior border of the left arm pit and was fully developed when I first saw the patient, an adult man. Incision and careful antiseptic dressing were practiced, but in two days a second boil appeared in the lower portion of the axilla, accompanied by enlargement of several contiguous glands. In spite of careful surgical treatment the infection of the glands had progressed until two had suppurated and been incised; then a well developed axillary adenitis with the usual mass of tender, indurated, confluent glands developed, and it was clear that the issue was a total extirpation of the infected mass or intervention with an artificial auto-inoculation. The first dose of a stock staphylococcus aureus opsonogen brought the adenitis to a check and three glands progressed to suppuration, became superficial, fluctuated, and were easilv evacuated. A second dose after six days, this time of the autogenous aureus opsonogen, promoted the resolution of the infected glands, and at the end of the second week when the third and last dose was given the whole indurated mass had melted away and a complete and perfect recovery was effected—all of this with the patient reporting personally for treatment, and losing but three days in his employment.

Staphylococcic Psoriasis.—Before dismissing this necessarily hurried account of staphylococcic infections I wish to recount one of my latest experiences which is so remarkable in its results as to call for a special and detailed account, although it comes in a group of results all of which are truly astonishing judged by any previous therapeutic standard. I refer to a case of what was designated by Dr. A. P. Biddle of Detroit, who had the woman under treatment twelve of the eighteen months of the disease, as psoriasis, but which the bacteriologic analysis showed to be a most extraordinary staphylococcus dermatosis, and which one dermatologist has defined as a seborrhoeic eczema. At the time I first saw the patient the disease involved at least one-third of the entire cutaneous surface of the body, and was of so aggravated a type as to make of her a physical and nervous wreck. The immense confluent lesions on the arms, legs, breast, back, sides and buttocks were slightly raised above the unaffected skin, of a dull red color and covered with large, thick scales, remindidg one of a piece of plate gelatin. Each night, and often twice daily, the woman annointed herself with olive oil and went through the trying operation of pulling off the scales, which she asserted would cover a newspaper, and which often left bloody, denuded surfaces exposed. A constant sensation as of a recent burn was suffered, and often an intolerable itching so that sleep of not more than hour's duration had not been possible for months; and with no relief during the day it is little wonder that the victim was on the verge of complete collapse when I first saw her. Movement of the arms or walking were most painful to her because of the cracking and erosion of the crusted limbs. Besides these confluent areas there were numerous discrete lesions on the limbs, trunk, face and scalp. The remaining skin was dry and harsh and did not perspire. The hair was coarse, dry and lusterless.

With the evident subacute inflammatory nature of the affection as a ray of hope I excised completely with aseptic precautions, one of the discreet lesions on the arm and placed it on glycerin agar. The next day I was rewarded by a pure culture of the staphylococcus aureus against which I found the patient's opsonic index low. An opsonogen from this culture was at once prepared and inoculated. That same night the patient slept two hours consecutively and the skin broke out in a mild perspiration. The next day the burning abated at intervals and the itching lessened. At the

end of the first week a remarkable improvement in the diseased skin was apparent and the physical and mental status of the woman greatly bettered. Six weeks from the time of the first examination and the event of the fifth injection of the staphylococcus opsonogen, both the confluent and discreet lesions of the arms and legs had given way to a normal looking skin covered with delicate fluffy scales, and the only evidences of the original fearful condition were two narrow, slightly elevated reddened crescents under the breasts. The woman, whose appetite had at once improved had been placed on a generous mixed diet to replace the restricted one previously prescribed, she had gained five pounds in weight, her strength and spirits had revived, she slept comfortably all night, her skin had become moist, soft and pliable, and her her hair had become soft, oily and with renewed luster. One additional point of interest was elicited in the previous history, that is, that the forerunners of the dermatosis were a boil on the wrist, one behind the ear, then a crop about the genitals, to be followed first by the discreet and later by the confluent dermatosis. As a supplement to this account I may now add that at present, four months since treatment began, this patient is still in excellent health. Several slight tendencies for the affected skin to become irritated have been successfully met by injections of the staphyococcus in doses of 500 millions at intervals of two to three weeks.

Eczema.—That some forms of eczema will be remedied by bacterial therapy is illustrated by my experience in a private patient, a young man, 20 years of åge. This individual had, as an infant, a generalized eczema of a most distressing kind which persisted for several years in spite of the treatment prescribed by a number of the leading dermatologists in various parts of the country. After this condition finally mended spontaneously, recurrent attacks were experienced, especially during the winter. It was for one of these attacks, which occurred some two months previously, that the patient consulted me. Both ears and the sides of the neck were in a weeping, acute eczematous condition, and overlaid with the usual crusts. The face was reddened as by a sunburn and covered with a scale exfoliation. On both forearms and across the breast was a reddened punctate eruption. The skin of the body as a whole was dry and harsh; the hair of the head was coarse, very dry, lusterless, and the scalp was the seat of dry dandruff so abundant as to be easily shed upon the clothing. This condition of the skin, of the hair and of the scalp had existed so long back as the patient could recollect.

Bacteriologic analysis of the secretion from the acutely diseased portions of the skin yielded *Staphylococcus citreus.* The staphylo-opsonic index was 0.65. Accordingly inoculations with the autogenous bacteria were instituted. Progress has been steady since this treatment, which supplanted all other measures, was begun. After the second inoculation the lesions on the arms and breast disappeared. The face speedily lost its reddened hue, the scales ceased to form, and a fine, clear complexion established itself. The areas on the ears and neck yielded more slowly, but steadily, and on the occasion of the last injection all marks of the eczema had disappeared except a slight, scaly coating over the seat of the worst lesions on the neck. A gain in weight has occurred. The skin of the body as a whole has become soft. A natural oily condition has appeared in the hair on the scalp and the dandruff has entirely vanished.

SEPTIC SURGICAL INFECTIONS.

Palmar Abscess.—A case of palmar abscess in a man was referred to me by Dr. George Sherman of Detroit. The hand and forearm were greatly swollen; a deep abscess was present in the center of the palm under the point of infection and much constitutional disturbance was in evidence. Two injections of streptolytic serum had produced no effect further than to lower the temperature, and Dr. Sherman made a small incision in the palm and brought me some of the pus in a sterile syringe. Immediate smears from the pus showed staphylococci and the first dose of 100 millions stock staphylococcus aureus opsonogen was injected. A halt in the progress began in 24 hours and in three days the improved general condition was accompanied by a reduction in the swelling. From the pus *Staphylococcus albus* in pure culture was obtained and an opsonogen prepared; the fourth inoculation with the autogenous bacteria in a dose of 150 millions was performed. The improvement became more pronounced, the suppuration more superficial, and an incision 1½ inches in length extending the original one was all that was required. Two more inoculations with the autogenous opsonogen in doses of 200 millions at intervals of a week completed the perfect recovery of this infection, with full healing of the incision and no impairment in the functional perfection of the hand.

Since this first experience I have treated several cases in which infection followed accidental or surgical injury to the fingers, hands or feet. Various grades of the infective process, from a localized inflammatory reaction in the neighborhood of the original focus of injury or operation to those in which spreading inflammatory œdema extended well up the arm or leg have been attempted. In all of these cases the invading microorganisms happened to belong to the group of staphylococci, and prompt, satisfactory arrest of the inflammatory process and early recovery without the usual suppuration and prolonged treatment by incisions, drainage, and antiseptics was brought about by the use of proper doses of opsonogens of autogenous origin. These cases have been seen in consultation with various Detroit physicians in private practice, and several have occurred in the surgical service of Dr. Theo. McGraw at St. Mary's Hospital.

Urinary Infection.—As an example of the truly astonishing results one may obtain by bacterial therapy properly applied I will again refer to my first case of colon bacillus infection. The patient was a retired physician afflicted with locomotor ataxia and consequent palsy of the bladder, followed by an infection of the bladder and the usual ascending urinary infection, producing a cystitis and pyelo-nephrosis and of three months' duration. The ordinary lines of medical treatment, including the use of urotropin had failed to bring relief, as had likewise such procedures as irrigation of the bladder with various antiseptic solutions; and the patient was bed-ridden, emaciated, profoundly septic with its usual train of anorexia, constipation, vomiting and prostration. The urine was foul in odor and loaded with thick, greenish-yellow, gelatinous pus which in a pint of urine settled to a layer one inch in depth. Chills, a daily temperature of 103 F., and profuse night sweats were established. The right kidney was plainly palpable and on its ventral surface one could feel a mass as large as a lemon, tender and apparently representing the dilated urinary pelvis. According to precedent such a case would of course be pronounced incurable, and except from the standpoint of endeavoring to make the remaining existence endurable, would be abandoned. I was called in consultation by Dr. Chas. D. Aaron, who

had been endeavoring to correct the gastro-intestinal disorder, to see this patient. From the pus in the urine I obtained abundant bacilli in smears, and a pure culture of what was identified as colon bacillus of the usual type. Against this bacillus the patient's phagocytic index was one-third less than that of the phagocytic index of a normal person's serum, that is to say, his opsonic index was about two-thirds normal. The usual preparation was made from the bacillus obtained from the urine and inoculations at intervals of five to ten days, five doses in all, varying from 200 millions to one billion bacilli, was practiced. The opsonic index rose in a pronounced manner. This however was less significant than the improved local and constitutional conditions of the patient. After the first inoculation his temperature arose above 100 F. After three days his chills and night sweats ceased not to reappear. The character of the urine changed during these first few days, the pus became less abundant, thinner, not so coherent, and the foul odor disappeared. From the first injection the improvement was progressive except for several gushes of putrid pus evidently representing the emptying of pyelo-nephric abscesses. The right kidney speedily lost its tenderness and the tumor on its surface disappeared. The patient, whose treatment began November 2, 1906, is now enjoying active out-of-doors life, his appetite is excellent and he has gained eighteen pounds in weight, with coincident improvement in strength and spirits. The urine at the worst contains but a small amount of thin pus, and ordinarily is clear. Even the distressing features of his neurosis have greatly improved as was evident when he recently walked a distance of three miles to visit me at my office. I have stood in readiness to intervene with further inoculations, but since the last one the progress has been so steady as to make further treatment superfluous. Apparently we have reached in this case what Wright would call a sustained "high tide of immunity."

Thoracic Empyema.—My first case of thoracic empyema was seen with Dr. George Sherman. The patient was a seven-year-old girl who had a severe atypical pneumonia, with a crisis at the end of a week. For ten days after the temperature remained at between 99° – 100°F., and then arose to 102°F., accompanied with some dypnœa, and pain in the right chest. Three days after this rise in temperature Dr. Sherman found dulness in the lower right chest and on exploratory aspiration obtained a thick pus in a sterile glass syringe. On my suggestion the poor practice of making a small intercostal incision and inserting a very small drainage tube was at once instituted with the evacuation of some eight ounces of thick pus but no expansion of the lung, evidently indicating a sacculated empyema. The next morning the pus was brought to the laboratory, smears showed a diplococcus, and by the next day following I had isolated the pneumococcus from which an opsonogen was prepared. Three days after obtaining the pus I visited the patient and gave the first inoculation of the autogenous bacterial preparation, containing approximately 20 millions pneumococci. I found her much emaciated, weak, fretful, with a hectic look, temperature of 100 F., pulse 120, and a profuse discharge of thick pus into the voluminous dressing. Four days later the attending physician reported a pronounced improvement, the appetite returned, strength increased, discharge steadily diminished until it was scanty and thin sero-purulent in character, and the small drainage tube had been pushed out by the expanding lung and could not be reinserted. On the sixth day only a small quantity of serum oozed from the opening against which the pleura had appeared. A second inoculation was then made. On the seventh day the wound had entirely closed, the little

girl was eating splendidly, and had gained in flesh and strength, and with no pain or fever. That gain has been uninterrupted until the present time, a month since the treatment. In other words, a perfect recovery of a sacculated empyema was effected in seven days by small puncture, evacuation of the bulk of pus, small drainage, and artificial auto-inoculation.

Another example of *unhealed empyema* has more recently been brought under my care by Dr. George W. Moran, who had operated on the patient, a six-year-old lad, eight weeks before. When I first saw this patient six to eight ounces of this greenish yellow pus was escaping daily from the opening in the chest. This amount of pus had drained for several weeks. The boy was weak, thin and haggard, and had the usual fluctuating temperature of extensive chronic suppuration. Among the bacterial flora of the pus was a streptococcus which I isolated and converted into an opsonogen. On Feb. 22, the first inoculation of 10 millions of these streptococci was made. In two days a pronounced fall in the febrile curve was noted and thereafter the temperature did not exceed 100 F. The amount of pus rapidly diminished until only a tablespoonful escaped in the 24 hours at the end of a week, when the second injection of 10 millions autogenous streptococci was performed. Ten days after the first inoculation the boy was allowed out-of-doors. He had gained very decidedly in flesh. His appetite was splendid. The drainage tube had been forced by the expanding lung out of the opening in the chest wall and not enough discharge to wet the dressing escaped in 24 hours. By the end of the second week full healing of the wound had occurred, and following this the boy passed through an attack of mumps with no further evidence of his thoracic disease.

Postoperative Fistulas.—A patient who had been operated for breast tumor with total extirpation of that organ and of the axillary glands, developed an infection of the wound followed by profuse suppuration and acute septic symptoms. After the acute manifestations had been controlled a sluggish unhealing state followed leaving a large denuded area, a deep fissure and a subcutaneous sac. Four months after all attempt to remedy this had failed and after a consultation between Dr. H. C. Walker and Theo. McGraw, I was invited to see the case. Mixed with several organisms from the pus was a streptococcus which I used as a source of an autogenous opsonogen. Inoculations with the streptococcos in average doses of 10 millions have been practiced at intervals of 7 to 10 days. The sluggish condition has mended, clean pus-free healing of the denuded area and of the fissure in the breast has gone on to practical completion. Only a portion of the arm wound which was covered with thin, poorly nourished skin now remains to heal.

In a patient with two persistent discharging abdominal fistulas following a cholecystotomy and appendectomy in Dr. McGraw's service in St. Mary's Hospital, a single injection of the autogenous streptococcus, in ten days brought complete cessation of suppuration and complete healing, so that the patient, whom I found bed-fast, was able to leave the hospital fourteen days after the first inoculation was performed.

BACTERIAL THERAPY OF GONORRHŒA.

My first essay in the bacterial therapy of gonorrhœa was made early last summer in a case of *balanoposthitis* and *gonorrheal urethritis* of eight month's duration, with the usual picture of an immensely swollen and phimosed foreskin and a thick scar-like preputial orifice. An injection of gonococcus

opsonogen representing about 10 millions gonococci from a culture that had been kept on artificial media for nearly a year was performed. On the second day following this treatment the swelling began rapidly to subside and by afternoon the patient reported with the foreskin retracted, the glans clean and free from redness or pus, and the urethral discharge much diminished. He stated that this was the first glimpse of the glans penis that he had had for eight months. Four succeeding injections effected a further diminution of the urethral discharge, which finally ceased entirely when a few urethral injections were used to reinforce the inoculations, and at last accounts the patient was well.

A further illustration of the rapid, specific action of the gonococcus opsonogen on the inflammatory complications of gonorrhea was seen in a case of *urethritis* of six weeks' duration, complicated with a *proctitis* of three weeks' standing, a *double epididymitis* for eight days, and a small periurethral abscess in process of formation. I saw this young man in consultation through the kindness of Dr. Andrew Sherman. Within 24 hours after the first injection of the gonococcus opsonogen all pain on urination and all backache had left, the swelling in the epedidymal tissues had subsided so rapidly as to cause a "crawling sensation" from the retracting dartos, the periurethral abscess had broken leaving a perineal urinary fistula. Following these events the patient's appetite returned and became insistent and he began a gain in flesh that continued until it had increased his weight 15 pounds, which was in excess of the previous normal. Several subsequent injections at weekly intervals have been given. The proctitis quickly disappeared and the urinary fistula so far closed that only a few drops of urine were lost once out of several urinations, and presently the fistula healed solidly with no local treatment directed to it. But the urethral discharge completely subsided only when argyrol injections were used to fortify the inoculations.

At St. Mary's Hospital I treated by the same method a left-sided gonorrhœal *epididymitis* of a month's duration, as large as a hen's egg, much indurated and exceedingly tender. In 24 hours after inoculation the mass had begun to reduce in size, was softer, and much less tender. In 48 hours all the swelling of the epididymitis had subsided except an induration limited to the head, and by the third day this had departed and the patient's general condition was so excellent that he was discharged from the hospital.

My constantly enlarging practice with chronic gonorrhœal discharges constituting the so-called *"gleet"* and representing various lesions like *prostatitis*, *vesiculitis*, *anterior* and *posterior urethritis*, and variously complicated as with a low grade arithritis or only an arthralgia, goes to convince me that proper bacterial therapy holds great promise for this class of disorders which are so obstinate or intractable by other methods of treatment. I have witnessed some most surprisingly satisfactory results in this class of cases in which improvement in the local conditions, as shown by clearing of a purulent urine, diminution or disappearance of gonorrhœal threads, abatement of joint pains and the like, has been attended by disappearance of the neurasthenia from which, as you all know,these patients suffer peculiarly. Usually it has been possible to accomplish a satisfactory result with the gonococcus opsonogen alone, but occasionally it has been necessary to employ an opsonogen from the secondary invading organisms like the staphylococci, the pseudodiphtheria bacillus, bacillus mucosus capulatus, or the colon bacillus, the necessity for which was determined by a prolonged study of the predominating flora in the pus or in the threads.

In the *gonorrhœal affections of women* my work is still too small to justify more than the prediction that here, also, bacterial therapy promises a great boon. And in those unfortunate examples of accidental *vaginitis* in infants, and in ophthalmia neonatorim I have already had sufficiently personal experience to say that opsonic therapy will prove a most important adjunct to other well established methods.

It will not be unwelcome news to you to learn that *gonorrhœal polyarthritis* or *gonorrheal rheumatism* can be conquered by the use of the specific opsonogen. In one of my first patients, from Dr. George Sherman's practice, the infection had existed four months and involved several joints. Progressive betterment of the arthritis with the departure of the swelling, pain and immobility was effected by four injections when the patient considered himself cured and no longer reported. In another instance a man who was sent to me by Dr. F. J. W. McGuire, was almost a helpless cripple with a gonorrhœal arthritis of four years' duration involving both wrists, both shoulders, one elbow, and one knee, all the affected joints being immovable or of very restricted mobility. The usual symptoms of pain, sleeplessness, cold sensation, cold sweats and physical and mental depression were in evidence. Seven injections at weekly intervals have worked a most surprising improvement in this man's condition. Practically all swelling and thickening of the joints have subsided, and all are now freely movable, the range being normal except for the left wrist. Along with the gratifying local improvement there has been a practical cessatin of joint pain, good restful sleep undisturbed by chilly sensations or sweats, a progressive improvement in appetite and a steady gain in weight, and with this a revival of spirits and a physical activity very pleasant to witness.

CONCLUSION.

In dismissing this necessarily hurried account of my clinical experiences in bacterial therapy I would remind you that only illustrative cases have been chosen and that these represent the general trend. My failures thus far have been confined to two cases of advanced pulmonary tuberculosis where the outlook was known to be unpromising and where no improvement followed a cautious use of tubercle opsonogen. I also made a single inoculation of a streptococcus from a badly infected foot and leg in a patient of Dr. Theo. McGraw's, where advanced *parenchymatous nephritis* and *uremia* existed. Getting none of the usual favorable results further inoculations were not attempted.

Not all cases inoculated with the proper bacterial opsonogen do equally well; some respond rapidly, others are more stubborn. A single inoculation may suffice to establish a sustained high tide of immunity, while again the treatment must be long and continued to reach this end. Indeed, as I have recently insisted, each case of opsonic therapy is a law unto itself, and this consideration applies not alone to the prospective outcome, but also to the task involved in determining the identity of the offending organism and to the judgment required in the use of that organism. And this brings me to speak a few words suggested by the many inquiries which have come to me from physicians in all parts of the United States since the first report of my clinical experience with Wright's therapeutic methods. An account of the remarkable success which attends the proper application of bacterial therapy is naturally most stimulating to every medical man who seeks to give his patients the benefit of all the resources of his art, and it is important that

the possibilities underlying the new method should be widely disseminated both in the profession and in the public. In the present stage of its development, however, the practice of opsonic therapy cannot become general without great jeopardy. It should for the time being, at least, remain in the hand of the comparatively rare worker whose training has been largely in the bacteriologic and pathologic laboratory, who has familiarized himself with practical immunology and sero-therapeutics, and who has, with these accomplishments, had sufficient clinical practice in medicine and surgery to enable him to apply with discriminating judgement at the bedside the knowledge gained in the laboratory. Unless the practitioners of opsonic therapy are thus restricted grave consequences may follow, for it must be known that we are dealing with potent biologic agents—potent for good—powerful for evil. The great dangers underlying incautious work in this new and difficult field can be best appreciated by those most skilled in its practice, and the many pitfalls that lie in the path of the opsonist, will, unless evaded by the requisite skill and experience, bring this most promising of therapeutic resources into disrepute both in our profession and in the laity.

The results which it has been my pleasure to recount as having been obtained in my personal experience are in general only duplicates of those reported by Wright and his followers in Great Britain. And it must be recognized that evidence which is now rapidly accumulating indicates that Wright's practice of bacterial inoculation, based on the opsonic index as a guide, opens a field of remedial possibility great in scope and wide in usefulness. As I have already intimated, many morbid affections considered incurable according to old standards, become conquerable, others of so chronic and intractable a nature as to overtax all previous medical and surgical resources yield in a manner surprising, and from the standpoint both of the physician and patient, most gratifying. We are still but on the outskirts of this new and promising field, and I believe that the day is not far distant when some of the complex features will be eliminated, and when many physicians will practice opsonic therapy.

Detroit, Mich.

THE INFLUENCE OF THE COMPOSITION OF THE MEDIUM UPON THE SOLVENT ACTION OF CERTAIN SOIL BACTERIA.

CHARLES W. BROWN.

If phosphate fertilizers, which are insoluble in water, are to be used economically upon soils deficient in phosphorus, it is necessary to know what agents are active in rendering the insoluble phosphates soluble; and to what extent these agents act. It is known that soil moisture, that chemical compounds in the soil, that acids secreted by the roots of plants, that the carbon dioxide held by the soil water, and that bacteria are the most important factors in the dissolution of insoluble phosphates. It is toward the soil bacteria that I shall direct my remarks.

When bacteria are isolated from the soil, it is obvious to say that we are cultivating them upon a medium somewhat different than the soil itself; but if we find that a certain soil bacterium, when grown upon culture media, is capable of dissolving insoluble phosphates, we may suspect that this germ, even while growing in the soil, does have the power of making phosphorus available to plants.

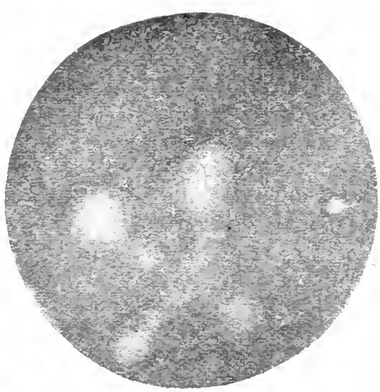
Several experiments have been carried on to determine the influence of the composition of the medium upon the solvent action of certain soil bacteria. The materials experimented upon are rock phosphate, bone, tricalcium phosphate, dicalcium phosphate and calcium carbonate. After these minerals are finely ground, the powders are shaken up with water and those particles which remain in suspension for over half a minute are poured into a filter and washed with water. A little of the washed powder is put into a flask of medium and sterilized in live steam under 15 pounds pressure for fifteen minutes. The sterilized medium is allowed to cool to between 50°C., and 60° C.; then shaken to distribute the suspended particles equally. Plates are poured by using a sterile pipette to transfer about eight cubic centimeters of the medium to a sterile Petri dish. They are inoculated by a stroke on the surface of the solidified medium, and placed in a temperature room at 22° to 23° C., to wait development. Here they are examined daily for a visible solvent action which is made apparent by the suspended particles near the growth of the germ disappearing. This is a crude comparative quantitative method for detecting the solvent action of bacteria, but if minute dissolution is to be detected, a more sensitive method must be resorted to.

Ordinary nutrient agar was tried as a medium, but in no case was there a visible dissolution of any of the five minerals tried.

Nutrient agar containing 2% dextrose was used. This time several of the germs showed an action upon the calcium carbonate and the dicalcium and the tricalcium phosphates, but no visible action was seen on either the bone or the rock phosphates.

A synthetic agar medium composed of .02% magnesium sulphate and ammonium sulphate respectively and 2% agar was tried with and without sugars. Into the first set of plates was poured the synthetic medium alone;

Photographs of Petri dishes showing the solvent action of bacteria upon finely divided and washed calcium carbonate and dicalcium and tricalcium phosphates that are held in suspension by a medium composed of soil leachings, 1½% agar and 2% dextrose. Nos. 1, 2, and 3 are calcium carbonate, dicalcium phosphate and tricalcium phosphate respectively.



into the second set, the synthetic medium plus 4% of saccharose; into the third, fourth and fifth sets was poured the synthetic medium plus 1%, 2%, and 4% dextrose respectively. Not a germ was found which gave any visible action in the plates containing no sugar; but in the presence of the 4% saccharose, the 1%, the 2% and the 4% dextrose, some of the germs gave a marked action, upon the calcium carbonate and the dicalcium and tricalcium phosphates. Some even dissolved those suspended particles which were, in cases, an inch from the growth of the germ. As before, no definite action could be noticed upon the bone or the rock phosphates. The solvent action of some germs seems to be greater in the presence of the larger percentage of sugar, while that of others seems to be as great with 1% as with 4%. Now, if we use meat infusion—a liter of water to a pound of beef—instead of the water in the synthetic medium, we find that the solvent action exerted by bacteria is not nearly so great.

In order to get the cultural conditions more nearly like those existing in the soil, we used a medium composed of soil leachings with 2% agar. No solvent action could be noticed. But when sugar was added to this medium the action is about as marked as that with the synthetic medium described above.

It might be interesting to note here that according to our experiments those germs which, in the presence of sugar, are the most active acid producers are also the germs which, in the presence of albuminoids and the absence of sugar, are the most active alkali producers. And again that these active germs are the ones which have shown the greater solvent action. In no case has there been any visible action shown by a germ which is feeble in changing the reaction of a medium. Twelve out of twenty-five bacteria isolated from the soil were found to give a definite, visible solvent action. One which, produces no gas but a larger amount of acid from sugars than any of the others, shows the greatest action upon the calcium carbonate, while other germs which produce gas—largely carbon dioxide—but not as much acid as the former, give an action more marked than that of the stronger acid producer upon the dicalcium and tricalcium phosphates. These points, with others noticed during the experiments, have led us to believe that, while acid is a great factor in dissolving insoluble phosphates, the carbon dioxide liberated from carbohydrates by the gas producing bacteria must not be overlooked as a solvent agent.

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THE SIGNIFICANCE AND CONTROL OF STARTERS EMPLOYED IN RIPENING CREAM AND MILK.

LELAND D. BUSHNELL.

The purpose of this paper is to discuss in a limited measure the difficulties in the commercial handling and control of starters or bacterial cultures.

The starter as a culture of bacteria in a medium, highly susceptible to contaminations, meets with many difficulties and when handled by some one almost totally ignorant of its nature becomes a source of trouble rather than a source of gain.

A starter as here mentioned is a culture of bacteria which is used to influence the fermentation changes when added to milk and cream. This process is called the ripening process. The chief agency in the ripening is the growth of bacteria and the production of certain substances. Milk being an ideal medium, bacteria develop very rapidly up to the loppering point. Counts made at this stage show as high as 10,000,000,000 per cubic centimeter. The development of this enormous number of bacteria must necessarily produce great changes in the chemical constituents of the milk.

As is well known, there are two prominent classes of micro-organisms acting upon milk, that tend to bring about these changes; those fermenting the milk sugar with the production of acid, and those exerting a proteolytic action upon the proteid substances with the formation of ammonia, and amido, compounds and other degradation products.

The relation of bacteria to the finished product are two-fold. First: The influence of bacteria during the ripening process before the manufacture. Second: the relation of bacteria to the finished product, and the changes which they produce therein.

Under the first heading comes a practical division of an increase in yield. In normal cream the fat globules are distinct from one another and do not coalesce. They are supposed to be held together and kept from floating freely by a fibrin like material normal to milk. With the ripening and the consequent production of acid this material is softened, thus allowing the globules to be more easily aggregated into lumps.

Under the second heading comes the keeping quality. This has more to do with the manufactured product. Butter and cheese contain more or less proteid material and sugar capable of being acted upon by micro-organisms with the production of undesirable compounds.

Among these are the amido compounds and butyric acid, which give the peculiar rancid flavors and odors so characteristic in old and poorly cured butter and cheese. The products resulting from the decomposition of the milk sugar by the lactic bacteria give rise to constituents that are at once desirable and tend to control the development of the micro-organisms causing the formation of undesirable substances. This ripening gives control of the bacterial content in the finished product, thereby increasing to a considerable extent the length of time it is possible to keep milk products in storage.

The most important feature of the ripening process is that of flavor and

aroma. These begin to develop with the ripening in the milk and continue through the curing and aging process, after the manufacture of the milk product. If the proper bacteria are present we get desirable results not found in unripened or poorly ripened milk. Prominent among the substances formed is lactic acid; but there are also many others, each having its characteristic odor or flavor. As an outcome we get many results during the ripening which materially influence the flavor and odor.

The starter is used to overcome obnoxious micro-organisms and add to the finished product the desired flavor, aroma, keeping quality and perhaps other essential properties.

There are two general classes of starters—The Natural and the Artificial or Commercial.

Under the head of natural are included all those originated by the operator himself. These are generally selected by obtaining some milk that has been loppered by the proper kind of lactic bacteria. It must have the desired flavor and odor, also a good firm curd, free from gas bubbles and whey. Skim milk, sour milk, buttermilk and whey are sometimes used in this capacity, though none of these are desirable, for the great amount of acid developed has killed off the better types of lactic bacteria, leaving only the resistant gas and spore producing forms present.

The commercial starter is a culture of bacteria that is sent out by various firms in solid or liquid form. These are usually cultures of carefully selected and tested bacteria, though not always, however. While different kinds differ as to activity at a given temperature it is generally a pure culture and when properly handled and developed may be depended upon to give unvarying results for an indefinite length of time. Under ordinary factory conditions this is almost impossible simply because the ordinary factory operator knows little or nothing about the nature of a starter, nor does he have the proper apparatus for obtaining sterile conditions, or of keeping them after he does obtain them. Soon his starter acquires a bitter flavor, a gassy curd, or a foul odor. These conditions are due to foreign bacteria that have found their way into the starter and developed sufficiently to overcome the lactic germs. Here we soon have similar conditions to those found in the natural starter.

The natural starter was the first starter used. Some soured milk was saved from day to day in cold weather and added to the milk and cream to hasten the ripening. This was not necessary in summer, because at that temperature the ripening took place rapidly enough. However, a demand on the part of the public for an acid butter led to its continued use. By an acid butter, is meant, one having the peculiar flavor of lactic acid present in an appreciable amount. If sweet cream is churned into butter we get almost the same flavors that are found in sweet cream; but if ripened cream is churned into butter we get the flavor and odor of lactic acid and other products of decomposition which are present in minute quantities.

Workers experienced trouble from the start by undesirable micro-organisms becoming so numerous in the starter as to overcome its good results. The culture became gassy, or developed too much acid in the desired length of time, thereby killing the desirable lactic types. Such cultures as this gave no end of trouble and other methods were devised. The use of heat to control bacterial growth in other industries led to its use in the handling of starters. Pasteurization was first resorted to with much better results. This, however, was not entirely satisfactory because of the resistant spore forms remaining, which in most cases exert a proteolytic action on the casein,

or ferment the sugar with the production of gas and other undesirable and uncontrollable conditions. Sterilization was next resorted to in preparing milk for the starter. Here all life was killed, thus leaving a clear field for the action of cultures added. Results obtained in this way were more satisfactory. The life of the starter was much prolonged, consequently the cost less and the results obtained greatly improved in uniformity.

In running a starter every precaution must be observed to keep it pure; the difficulty with the ordinary methods of transferring, by pouring from one vessel to the next, has been that after a few transfers the gas producing bacteria, so common in the air of the factory predominate and our starter is ruined. Methods were devised whereby small bottles or swabs were attached to the end of a wire and sterilized with the milk. These were used for transferring a small amount from one bottle to another from day to day, care being taken as in the transfer of any bacterial culture.

To run a starter by the latter method it is necessary to have sterile conditions throughout for the building up and the transfer of the mother starter. It is best to sterilize about a pint of milk in glass milk bottles. They should be heated in running steam for thirty minutes each day for four consecutive days. After cooling to below 100° F., it should be inoculated with a culture and placed at the proper temperature to develop in 24 hours. This is the beginning of the mother starter, and is to be transferred daily into the bottles of sterile milk by using one of the transferrers, before mentioned. Whatever remains in the bottle is added to some pasteurized skim milk which is allowed to sour and added to cream to be used for butter making and to milk to be used for cheese making. The percentage to be added, the temperature at which it is carried, and the length of time the ripening should continue are matters controlled by conditions surrounding the operator.

Agricultural College, Mich.

SOME RECORDS OF THE FALL MIGRATION OF 1906.[1]

NORMAN A. WOOD.

During the fall of 1906 the writer was permitted to spend the time intervening between September 8 and October 16 at Portage lake, Washtenaw County, Michigan, and during this time made notes on the birds observed each day. It seems advisable to publish these records for their bearing on the fall movement of migrant species.

DESCRIPTION OF THE LOCALITY.

Portage lake is about sixteen miles northwest of Ann Arbor, Michigan, and is situated in the "Interlobate Lake Region" which occupies the entire region shown in the upper left hand corner of the topographic map known as the "Ann Arbor Quadrangle." This region is made up of morainic knobs, lake basins, abandoned glacial drainage channels, and sand plains. The hills are steep, the plains dry, and the lakes and swamps drain into the Huron river which enters this region from the northeast. The Huron river and its valley, with its old drainage channels, of which the most important is the one at Ann Arbor, is doubtless an important migration route, and provides a direct and easy route for the dispersal of southern river valley species.

As the birds seem to follow this valley to some extent in their migration, the situation of Portage lake is an especially favorable one for their observation, notwithstanding the fact that many species which use this route in the spring seem to pass to the east or west in the fall migration. On the other hand many of the species which migrate in the spring too rapidly for accurate observation may linger for days in the fall if the food and weather conditions are favorable.

My observations were particularly confined to the narrow triangular shaped plain which separates Portage and Base lakes. This plain converges from a width of one-half-mile nearly to a point at its lower or southern end, where the outlet of Portage lake, which is about one-quarter mile below the exit from Base lake, empties into the Huron river. The elevation of the plain also descends towards this point which was evidently at one time under water, as the soil is composed of marl and muck. Owing to the lowering of the water level, however, the region is now much drier and overgrown with willow, ash, elm and some soft maple. This habitat, as determined by almost daily observation, was apparently a favorite one for many of the birds, especially warblers, vireos, thrushes and wrens.

As before stated the plain rises gradually to the northward from the point. Its soil on the higher parts is gravel and sand. On the eastern part of this plain, at the present time, there are cultivated fields that extend to the shore of Base lake; the western part is given up to an apple orchard of about 20 acres, with farm buildings at the northern end. On the west the orchard extends to the edge of the plain which falls off steeply, 20 or 30 feet, to the sandy beach of Portage lake. This steep bluff is thickly covered with trees of red and white oak, smooth-bark hickory and red cedar, the latter having

1 From the University Museum, University of Michigan.

also become scattered through the orchard, apparently through the agency of the birds which eat the seeds. The Waxwing or Cedar Bird is especially fond of these berries, and I have seen flocks of them feeding in these trees. Along the steep bank are a number of cottages, but as these are vacant during the greater part of the year and especially during the season of migration, they do not materially affect the bird life.

To the north of the orchard the bluff which forms the edge of the plain swings away from the lake leaving a low, wet wood of several acres, composed of soft maple, elm, and ash trees. The northern part of this wood is bordered along the lake shore by willows and sedges. Still further north, and to the end of the lake, the tamarack forms a more or less narrow but continuous fringe of swamp forest which extends along the low, wet border of the lake, in places reaching the margin, which is covered with coarse grass and rushes.

The bluff at this point is grown up with forest trees and bushes, as to the southward, and there is thus a long stretch of forest habitat along the lake shore, which not only furnishes a place where many of the migrant forest birds may stop to feed, but also affords a cover which is an efficient protection from the birds of prey.

DAILY OBSERVATIONS.

September 9.—The early migrants were apparently gone on this date. The Bobolink gathered into flocks in late July and August. The Scarlet Tanager, the Baltimore and Orchard Orioles, and the Yellow Warbler were not seen after August 26th. A large flock of Killdeer arrived at the lake about September 1st, and many of them were shot by gunners. On this date I saw eight, apparently the remainder of the flock, feeding on the beach which was uncovered by the very low water.

September 10–11.—But one new bird, the American Coot, was observed on these dates. Large flocks of Bronzed Grackles were observed flying over the lake, and I saw large flocks of Redwing Blackbirds feeding on the wild rice which is plentiful on the Huron river.

September 12.—Several Wilson's and a Hermit Thrush, also a Towhee, were seen in the woods near the outlet. A flock of Chickadees, one Golden-crowned Kinglet, and several Flickers were feeding in the trees in the orchard.

September 13.—The calls of many birds were heard in the night as they passed overhead on their journey southward. In the morning a Pied-billed Grebe was seen on the lake. Along the bluff, flocks of Cedar Birds were feeding on the berries of the red cedar. Flocks of Song and Vesper Sparrows were feeding among the weeds near the edge of the tree covered bluff to which they hastened when disturbed.

September 14.—A Marsh Hawk was observed quartering over the marsh, and a Great Blue Heron and several flocks of Cedar Birds flying over the lake. About sunset I saw a small flock of Black Ducks alight on the lake. A nest of this species was found near Dexter about May 1st, 1906, and four of the young were reared. When I saw them in September they were as tame as the domestic ducks they were with. I have also seen small flocks of this species in this region during the summer, so that a few evidently breed here.

September 15.—Near the outlet two Warbling Vireos and several Brown Thrashers were seen. On the lake an Osprey was observed catching fish.

Several flocks of Cedar Birds were seen in the woods along the bluff, and in the orchard. About sundown a flock of ten Mallard Ducks flew over from the direction of Base lake and settled on Portage lake. This species breeds occasionally in the marshes of this region.

September 16.—Several flocks of Chipping Sparrows, and two Mourning Doves were seen in the orchard, and Vesper Sparrows along the edge of the bluff. A Marsh Hawk was seen flying over the low, wet marsh at the edge of the lake.

September 17.—Three Kingfishers were observed catching minnows which came in large schools into the shallow water near the shore. These were swallowed whole as a rule, but when too large the birds carried them to the wharf and picked them to pieces. The Myrtle Warbler and Red-breasted Nuthatch were seen on this date.

September 18.—Several Crows were seen, also large flocks of Meadow Larks and Robins. In the orchard two Phœbes were busy catching insects, and large flocks of Song, Vesper and Chipping Sparrows were found along the fences and wooded bluffs.

September 19.—In addition to the species of sparrows observed on the 18th, the Field Sparrow (in small flocks) was seen on this date; also Bluebirds, Blue Jays, Crows, Robins, Cedar Birds, and the Hairy and Downy Woodpeckers. A fine adult female Wood Duck was seen at close range on the lake. This species also breeds here, as a female with a brood of ten half-grown young was seen by the writer on July 2nd, on the outlet of Portage lake. These young were still unable to fly and were doubtless hatched in the vicinity.

September 20.—The first Nashville Warbler was seen in the morning, in the willows along the edge of the lake. Near the outlet a Northern Yellow-throat was also seen, while in the orchard the Yellow-bellied Sapsucker was observed for the first time this fall. Flocks of Field, Song, Chipping and Vesper Sparrows were feeding in the weeds along the edge of the bluff. A flock of Blue Jays was observed feeding on the acorns of the red, and white oaks near this spot. Several flocks of crows were flying over in a southeast direction, and large flocks of Redwing Blackbirds seemed to be gathering here from all directions. A flock of eight Coots was seen on the lake.

September 21.—Early in the morning the first Winter Wren was found along the edge of the river near the outlet. This is the earliest fall record known to the writer for this vicinity. A number of Magnolia Warblers were feeding in the tops of small willow and ash trees near the outlet. A few Myrtle Warblers, Catbirds and Thrushes were seen near the water's edge. On the lake a few Coot were seen.

September 22.—In the orchard on this date Phœbes, Bluebirds, White-breasted Nuthatches, Chickadees, and many Song, Vesper and Chipping Sparrows were found. A large Osprey was seen on the lake, evidently feeding on the Lake Herring which were dying in numbers and rising to the surface. About sundown an American Bittern flew from the edge of the lake to a small island covered with rushes. On rowing near the spot I could see him settled for the night on a thick bunch of rushes. A roost of Redwing Blackbirds was found at the outlet of Pinckney Creek, where about sundown great flocks of these birds with a few Bronzed Grackles gathered in the tops of the high ash trees and gave a grand chorus. As the sun went down these flocks commenced to fly down and settle for the night in the thick tall rushes at the water's edge. On clear nights the flocks came until dark and settled noisily, but when it was cloudy or raining they came earlier and were less

noisy. At daylight they commenced to scatter, most of them going up or down the river where the wild rice is very plentiful. This roost was still occupied by hundreds of birds on October 16th.

September 23.—The only new species seen on this date was the Tree Sparrow which was found in the bushes near the outlet. Four Pied-billed Grebes were on the lake also near the outlet.

September 24.—No observations were made on this date.

September 25.—A large flock of about fifty Blue Jays was seen high overhead. Near the outlet and in the bushes along the road a large flock of White-throated Sparrows were found, the first seen this fall. In the orchard several Red-breasted Nuthatches, apparently new arrivals, were seen.

September 26.—A Swamp Sparrow was taken on this date at the edge of the tamarack woods. This was the first one seen. In some alder bushes in the immediate vicinity a fine Solitary Vireo was taken, this is the only fall specimen ever seen here by the writer. Flocks of Field Sparrows were seen in the hedge rows, and several Red-breasted Nuthatches in the orchard. The first Olive-backed Thrush was also taken at the edge of the tamarack belt, and two Ruffed Grouse were seen. Many White-throated Sparrows, and a flock of Juncoes were noted for the first time. A small flock of Mourning Doves (flying over) and the Downy and Hairy Woodpeckers, Yellow-bellied Sapsuckers and White-breasted Nuthatches were seen in the orchard. In the evening a Whip-poor-will was heard calling, in the woods near the outlet.

September 27.—Near the outlet the Bay-breasted and Blackpoll Warblers were seen feeding in the willows near the edge of the water, and the Northern Yellow-throat was still to be found in the thick brush along the road, with flocks of White-throated, Song and Chipping Sparrows and a few Catbirds and Brown Thrashers. In the orchards were flocks of Flickers, Chipping Sparrows, Chickadees, Bluebirds, and a few Phœbes and Yellow-bellied Sapsuckers. Numbers of Myrtle Warblers were observed feeding on the ground, a habit I have never before observed in this species. Large flocks of Crows flew over the lake, and on the river I saw a few American Coot.

September 28.—Early in the morning of this date near the north end of the lake a flock of between eighty and one hundred Towhees was seen. This is the largest flock in my experience; both sexes seemed to be represented in about equal proportions. A flock of American Goldfinches was also seen on this date, and in the orchard the first Ruby-crowned Kinglet of the fall migration was observed. Numbers of Myrtle Warblers were seen to light on the ground, apparently to feed. An Osprey was again fishing on the lake, and just before dark a flock of eleven Wood Duck lit near a small grassy island where with considerable noise and commotion they seemed to be preparing to spend the night. The American Bittern before mentioned came again and settled on the island where I had seen it before.

September 29.—In the orchard were seen Myrtle Warblers, Chipping, Song and Field Sparrows, Bluebirds, Phœbes and Flickers. On the lake were three Pied-billed Grebes, two Coots, and the Osprey circling over. In the evening I made a visit to the Bronzed Grackle roost at the mouth of Portage river, where it empties into Little Portage lake. This vicinity is marshy and covered with tall rushes and thick willow bushes, and for the last five years to my knowledge has been a rendezvous for this species and a few Redwings. My observations this year extended from September 10th to October 26th, at which time they still occupied the roost. On the evening of September 29th it was raining and as flock after flock came to the roost

they uttered only a few call notes as they flew low down just above the water and settled in the willow bushes. A low subdued murmur gave some idea of the great number of individuals. When the weather is clear the grand chorus of voices can be heard nearly a mile away.

September 30.—On the forenoon of this day four Ruffed Grouse were seen at the side of the road near the outlet, in a thick tangle of wild grapevines. These birds are very fond of the grapes and are often found in the fall in such places. A single Killdeer was heard calling.

October 2.—Flocks of Juncoes, Towhees, Tree and White-crowned Sparrows, Crows, Jays. Robins and Bluebirds were seen on this date. Many of them may have come in during the night as they seemed greatly fatigued. On the lake a flock of Mallard Ducks was observed. At 8 p. m. a Ruffed Grouse was heard drumming. It was a clear moonlight night and the bird was not far away, although the noise was soft and subdued. Although it is often heard just after sunset this was the latest hour that I ever heard it

October 3.—A Hermit Thrush, a Ruby-crowned Kinglet, and an Orange-crowned Warbler were taken on this date. This is apparently the second fall record of the latter species for Michigan, and the first for this county. W. W. Cooke states that but few fall records have been made. This bird was feeding in the tops of the red cedars on the bluff, in company with another individual which I took to be of the same species, but as they were almost constantly in motion I could not be certain in my identification. About noon a flock of about one hundred Robins was seen at a considerable height flying toward the south. About sundown a flock of Black Ducks flew over the lake, and in the evening a Screch Owl was heard in the trees along the bluff.

October 4.—No new arrivals and very few birds were seen on this date, probably owing to the inclement weather.

October 5.—A small flock of Rusty Grackles was seen along the shore of the lake, where they seemed to be picking up food from the beach. A number of Swamp Sparrows were found feeding on the seeds of the sweet clover near the edge of the willows at the foot of the bluff, and large flocks of Myrtle Warblers were feeding in the orchard with Song and Chipping Sparrows, Chickadees, Robins and Bluebirds.

October 6.—The same birds observed as on the preceding day, with the addition of the Marsh Hawk and Mourning Dove.

October 7.—Observations as on the preceding day, with the addition of the Red-tailed Hawk.

October 8.—In addition to the birds seen on the past few days a Sharp-shinned Hawk was seen in the orchard.

October 9.—Several flocks of Golden-crowned Kinglets, a few Sparrows and Mourning Doves, a Phœbe, and flocks of Juncoes and Tree Sparrows were observed. On the lake about twenty Coots, a Great Blue Heron and one Greater Yellow-legs were seen. Large flocks of Bronzed Grackles, and Red-winged Blackbirds still occupied the roosts.

October 10.—Doubtless owing to the cold and stormy weather (with snow) the birds were in hiding for the greater part of the day. A Kingfisher, Killdeer, Great Blue Heron and Greater Yellow-legs were seen about the lake, and in the orchard several Song Sparrows, a Chipping Sparrow, a Phœbe, Robins, Crows, Jays and Flickers. In the evening a Barred Owl was heard.

October 11.—The margin of the lake and the ground was frozen on this date. Three Greater Yellow-legs and a flock of fifteen Redhead Ducks were seen about the lake. A Winter Wren was found, and also the first Fox

Sparrow. Myrtle Warblers, Bluebirds, Robins and Phœbes were seen in the orchard, and Chipping and Field Sparrows along the bluff.

October 12.—A flock of six Greater Yellow-legs, a few Killdeer, and a small flock of rusty Blackbirds, were seen feeding along the beach. On the lake were seen a flock of Redhead Ducks and over the water a couple of large Gulls (immature Herring Gulls) and a Broad-winged Hawk (the first record for the fall). In the bushes near the outlet a Woodcock was seen, and flocks of Robins, Bluebirds, Crows and Jays; also a few Phœbes in the orchard.

October 13.—In the willows along the edge of the lake a Woodcock was seen. Several of the species seen on the 12th were observed again on this date, but in less abundance; this was especially true of the Warblers and Thrushes. A Great Horned Owl was heard in the afternoon.

October 20–21.—On these dates a few Robins, Bluebirds, and one Phœbe were seen in the orchard; also the White-breasted Nuthatch, Downy and Hairy Woodpeckers, Flicker Jay Crow and a few Song and White-throated Sparrows. The Red-winged Blackbirds and the Bronzed Grackles still occupied the roosts at the mouths of Portage river and Pinckney creek. On the lake one Pied-billed Grebe, a few Herring Gulls and several Ducks were seen. In the evening the Barred and Screech Owls were heard. In the afternoon of October 21st a Ruffed Grouse was drumming in the woods across the lake.

Ann Arbor, Mich.

MUSEUM METHODS.[1]

F. S. Hall.

In the limited time which I have at my disposal I shall endeavor to present in a concise manner and from an executive standpoint, a few of the problems which confront a modern museum, and to describe briefly how some of these problems have been met at the Museum of the University of Michigan. Speaking generally of the public at large, which also includes many professional men in subjects closely allied to museum work, there seems to be a general ignorance as to the real purpose and aim of the museum of the present day. The prevailing opinion in the past and to a great extent at the present time is, that a museum is a repository and exhibition place of curios and freaks gathered from different parts of the world. There has been reason for this belief as many of you are aware, and up to within a few years we have been mostly familiar with ill-mounted specimens of mammals and birds, regiments of shells marshalled in pasteboard trays, cases of insects, etc., in many instances moth-eaten and covered with dust, and arranged without regard to anything but their taxonomic order. Such was the museum of the past, but the modern museum is an entirely different affair, at least in the best instances. That the American public is awakening to this fact and beginning to appreciate the educational value of the museum is illustrated by the numerous articles that have recently appeared in several prominent monthly magazines, on the different phases of museum work in the larger American museums, notably the American Museum of Natural History of New York, and the Field Museum of Natural History of Chicago, which in many respects serve as models for the smaller institutions.

In a lecture delivered before the Brooklyn Institute in 1889 on "The Museums of the Future," G. Brown Goode[2] has outlined the true scope of the modern museum in the following words:

"The museum of the past must be set aside, reconstructed, transformed from a cemetery of bric-a-brac into a nursery of living thoughts. The museum of the future must stand side by side with the library and the laboratory, as a part of the teaching equipment of the college and university, and in the great cities cooperate with the public library as one of the principal agencies for the enlightenment of the people."

To particularize and come nearer to the scope of a museum like the one here at the University of Michigan, I can do no better than to give a general resumé of the special aims of a local museum as formulated by a museum committee of the British Association for the Advancement of Science.[3] They are as follows:

"1. To contribute its share to the general scientific statistics of the country by collecting and preserving specimens of natural production of the district in which it is situated.

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1 From the University Museum, University of Michigan.

2 1889. Goode, G. Brown, "The Museum of the Future." Rept. U. S. National Museum, 1889, p. 427.

3 1893, Morse, Edw. S., "If Public Libraries Why not Public Museums?" Rept. U. S National Museum, 1893, p. 777.

"2. To procure such other specimens as may be desirable for illustrating the general principles of science, and the relations of the locality to the rest of the world.

"3. To receive and preserve local collections or single specimens, having any scientific value, which the possessors may desire to devote to public use.

"4. So to arrange and display specimens collected as to afford the greatest amount of popular instruction consistent with their safe preservation and accessibility as objects of scientific study.

"5. To render special assistance to local students and teachers of science."

As a matter of convenience museums may be classed in two general groups, namely, the Art Museum and the Natural History Museum, and as G. Brown Goode states, the difference between the two is "based on methods of arrangement, rather than upon the nature of the objects to be arranged."[1] The Natural History Museum, which is the one in which we are particularly interested, concerns itself with the sciences of geology, botany, zoology and kindred subjects. In regard to natural history objects, "not only do they require special methods of preservation, but very often their value as museum specimens depends entirely upon the skill, labor, patience and knowledge expended upon them."[2]

There are two classes of people with which the museum comes in contact, namely the general public and the student. To meet the demands of these two classes the collections in a Natural History Museum must be of two kinds—the "exhibition series," or those specimens placed on public exhibition, and the "study series," or those specimens which are kept in the private rooms of the museum for purposes of research and study.

That part of a museum which is most familiar, and the one designed to be the most instructive to the general public is the "exhibition series." To be effective this series should be not merely a collection of curious and unfamiliar objects arranged in a haphazard manner and with the sole aim of evoking expressions of astonishment, but they should consist of typical specimens grouped to illustrate certain definite facts or relations, such as life history, geographical distribution, habits, evolution, variation, migration, selection, anatomy, etc., so as to have a definite educational value. Excellent examples of the advancement which have been made along some of these lines may be found in the American Museum at New York, as illustrated by the artistic reproductions of natural environments in the life history groups of birds, mammals, etc., and in the Field Museum at Chicago, especially in the life history group of Virginia Deer, which is one of the finest groups of the kind in America. Here at the Museum of the University of Michigan some exhibits of the local fauna have been attempted as in the case of the birds arranged according to periods of migration; also the proposed group of domestic pigeons, showing the influence of artificial selection.

Sir William H. Flower, a noted English naturalist and British Museum director, has stated that the absolute requisites of exhibits are "correct classification, good labeling, isolation of each object from its neighbor, the provision of suitable background, and above all of a position in which it can be readily and distinctly seen."[3]

What is known as the "study series" is of the most importance to the

1 1889, Goode, G. Brown, "The Museum of the Future." Rept. U. S. National Museum, 1889, p. 440.
2 1898, Flower, Sir Wm. H., "Essays on Museums," p. 32.
3 1898, Flower, Sir Wm. H., "Essays on Museums," p. 33.

student. This series is not for exhibition, but is kept in private rooms or storage galleries of the museum. The primary object of this collection is for research, and it should be used only for consultation and reference by those whose education and knowledge qualify them for its use.

This series should be of sufficient size to meet the needs of advanced students, and the aim should be to make it as complete a collection of well selected and determined specimens of representative groups as possible. "The specimens kept for research, for advancement of knowledge, for careful investigations in structure and development, or for showing the minute distinctions which must be studied in working out the problems connected with variations of species according to age, sex, season, or locality; for fixing the limits of geographical distribution, or determining the range in geological time, must be not only exceedingly numerous (so numerous, indeed, that it is almost impossible to put a limit on what may be required for such purposes), but they must also be kept under such conditions as to admit of ready and close examination and comparison."[1]

By having a large "study series" the larger museums are able to offer particular advantages to the research student, and in many cases as much or more research is being carried on in our museums than in many of the universities. This emphasizes the importance of giving the best of care and attention towards making this series as valuable a working collection as possible.

In the arrangement of specimens designed for the "study series" the principal points to be aimed at are: "The preservation of the objects from all influences deleterious to them, especially dust, light, and damp; their absolutely correct identification, and record of every circumstance that need be known of their history; their classification and storage in such a manner that each one can be found without difficulty or loss of time; and, both on account of expense as well as convenience of access, they should be made to occupy as small a space as is compatable with these requirements."[2]

The class of specimens which compose the "study series" may, in a small museum, be divided into three general groups, namely, geological, botanical and zoological. It is of the latter group which I wish to deal with in this paper.

Generally speaking, at the Museum of the University of Michigan, the most convenient divisions of the animal collections have been found to be mammals, birds, reptiles, fish, amphibians, pinned insects and other invertebrates. Because of their nature each of these groups requires different methods of treatment and care. In the University Museum the mammals and birds, after coming from the taxidermist, are catalogued, labeled, and stored away in metal storage cases (which are pest, dust, and light proof), and are arranged therein according to some standard check-list, the birds according to the revised American Ornithologists' Union check-list. The skulls of all mammals are kept in separate storage cases and are arranged in the same order as the skins. The cases are all numbered consecutively, and by referring to the card catalogue which is kept of each of these collections, one may find in a very few moments any specimen desired, or he may assemble a series of specimens from any particular locality in a very short time. For instance, if an ornithologist wishes to compare several species of birds, he can, by going to the card catalogue, obtain the case number of each group, and in a few minutes have at his disposal the entire series.

1 1898, Flower, Sir Wm. H., "Essays on Museums," p. 15.
2 1898, Flower, Sir Wm. H., "Essays on Museums," p. 16.

The methods of preserving alcoholics is quite different. In the case of reptiles, amphibians and fish, a block tin label is used instead of paper labels, and the specimens are immersed in alcohol. The strength of alcohol used varies according to the class of the specimen; these are stored in a room especially reserved for that purpose and are arranged according to the taxonomic groups to which they belong. For convenience in locating the specimens belonging to these groups, and for keeping all of the data close at hand a card catalogue is kept of each group, as in the case of birds and mammals. A collection of pinned insects is generally a part of every museum, and because of its nature as many problems probably arise as to its care as in almost any other collection in the museum. *First*, the number of species with which a museum has to deal is extremely large, and their proper identification takes time and careful study. *Second*, many of the specimens are so small and delicate that a great deal of care must be taken in handling them to avoid injury. *Third*. Such collections are subject to pests which may infect them, and because of this they must be carefully examined and if need be disinfected at short intervals. The University Museum has found that a good method for keeping such specimens is in Comstock insect boxes which are placed in large wooden cabinets and arranged according to their taxonomic order. Other invertebrates such as leeches, crayfish, worms, spiders, small molluscs, etc., are preserved in alcohol. Such specimens are generally placed in wooden racks and placed upon the shelves in the "alcoholic room" in the section reserved for the particular group to which they belong.

Before bringing to a close this section which I have devoted to the "study series" of a Natural History Museum, mention should be made of the necessity of a working library on the subjects connected with the specimens of this series. It should be in close proximity to the storage rooms in which such specimens are kept, and should include the standard check-lists, reference books, etc., which it is necessary to consult in the study of the specimens.

According to present day ideas, much of the value of the specimen lies in what is known regarding it, i. e., the locality from which the specimen was secured, habitat relations, when it was collected, who collected it, etc. Methods must be perfected by means of which such data may be kept in such a way that it may be quickly and easily available when needed. There are three principal phases of the problems here involved, namely, accessioning, general and card cataloging.

The plan that has been adopted by the University Museum for recording the data of a specimen upon its arrival is the Accession Card System, and so far this has proved very satisfactory. A card (with a printed form) is filled out at once upon the arrival of a specimen, with all the available data pertaining to the object, such as, Date of collection; Locality; Collector; Accession Number, etc. This card is a part of a card catalogue system, and as soon as it is made out and the specimen catalogued, the catalogue number is stamped upon it, and it is placed in the card catalogue case, and arranged in the alphabetical order of the contributors.

The next step is the listing of the data in a permanently bound volume known as the "General Catalogue," and giving to the specimen a catalogue number. This catalogue has appropriately printed titles at the head of each column which is to be filled in with the corresponding data, and at the side are printed the catalogue numbers arranged in consecutive order. The data is then entered in the Card Catalogue, and the number tied on the specimen which is then placed in its proper place in the collection.

The card catalogue is an indispensable aid in museum work, for it enables one to find a specimen or refer to the necessary data pertaining to any specimen or species at short notice. The card catalogue has the following advantages:

1. The cards can be grouped by subjects or species.
2. Individual cards can be removed when they become obsolete, by the specimen being exchanged or destroyed.
3. New cards can be inserted whenever new material has been added to the museum.

A card catalogue is arranged taxonomically for each particular group of specimens in the museum collection, and includes both the specimens in the "exhibition" and "study series." A similar catalogue of equipment, and of the books and pamphlets included in the museum library is also an essential feature.

Another very important problem that confronts the museum of today is that of labeling. The labels are of two kinds, the descriptive label for exhibits, and the distinguishing label which bears the name and data. In the preparation of the former the widest and most accurate knowledge is essential. The information it is intended to convey should be set forth in a terse, concise and definite phraseology, and at the same time call attention to the essential points of the specimen which the visitor should observe. The service which the descriptive label does in the education of the public is undoubtedly one of the most important factors in making the museum what it is. I may quote Prof. Goode again by saying "an efficient educational museum may be described as a collection of instructive labels, each illustrated by a well selected specimen."[1]

Under the head of "distinguishing" labels come those labels which are placed upon all specimens, either in the form of the catalogue number alone, or a paper label which is tied securely to the specimen, giving name, locality, date and collector. On account of the variety of material dealt with in a museum, different methods of labeling are used for each variety, i. e., skins have paper labels securely tied to them, while alcoholics have block tin labels or cloth labels, instead. It is absolutely necessary that there should be a distinguishing label of some description with every specimen, for without it it is practically valueless.

In the above paper I have not attempted to compile a detailed set of museum directions, but merely to outline some of the more technical problems which confront all Natural History Museums, more especially those of a local type, and to give a general basis that may be used in the organization of such museums.

Ann Arbor, Mich.

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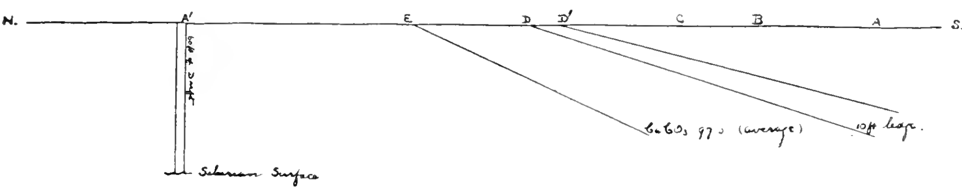
1 1889, Goode, G. Brown, "The Museums of the Future." Rept. U. S. National Museum, 1889, p. 433.

THE GEOLOGICAL CONTINUITY OF ESSEX AND KENT COUNTIES, ONTARIO, AND MONROE AND WAYNE COUNTIES, MICHIGAN.

REV. THOMAS NATTRESS.

When requested by the secretary of the Geological Department of the Academy, and at the instigation of the State Geologist of Michigan, to prepare a paper to be read here, I recognized in the request a challenge to solve a problem. That problem is to explain the presence, elevation, dip, and nature of the outcrop of the Corniferous (*or Dundee) in the Amherstburg Quarries, in Anderdon Township, Essex county, Ontario. According to the ascertained lines of outcrop of Silurian strata on the Michigan side of Detroit river at its mouth, the same Silurian surface extension would be looked for in the Southern half of Essex. But it isn't there—except in the river bed, and northward of Lime Kiln Crossing ashore. In its place is an outcrop of Corniferous, with southwesterly dip at the Amherstburg Quarries, and maximum elevation of 609 feet. The successive lines of outcrop in Ontario and Michigan, concentric in the coal area of Michigan, would lead one to expect a north to northwesterly dip. But the natural expectation is denied by the contrary fact.

The several strata, from the bottom of the high grade limestone deposit which lies immediately upon a brown dolomite, up through the heavy-bedded rock, to the surface of the thin-bedded limestone, thin out to nothing, as illustrated in the accompanying diagram by the heavy 10 ft. bed DD[1].



From A to B in the diagram is drift. From B to E is a Devonian rock surface. From E northward the rock (which is Silurian) falls away rapidly, until at A[1], less than forty rods away, it is 50 feet down, a depth of drift that is fairly uniform over a large area of the middle western part of the county. There may be a fault in the Silurian here. But, if so, it would explain nothing in regard to the Devonian outcrop.

The evidence goes to prove a Silurian anticlinal, northward of the Devonian deposit in Anderdon, upon which the Corniferous strata have been deposited with south to southwesterly dip.

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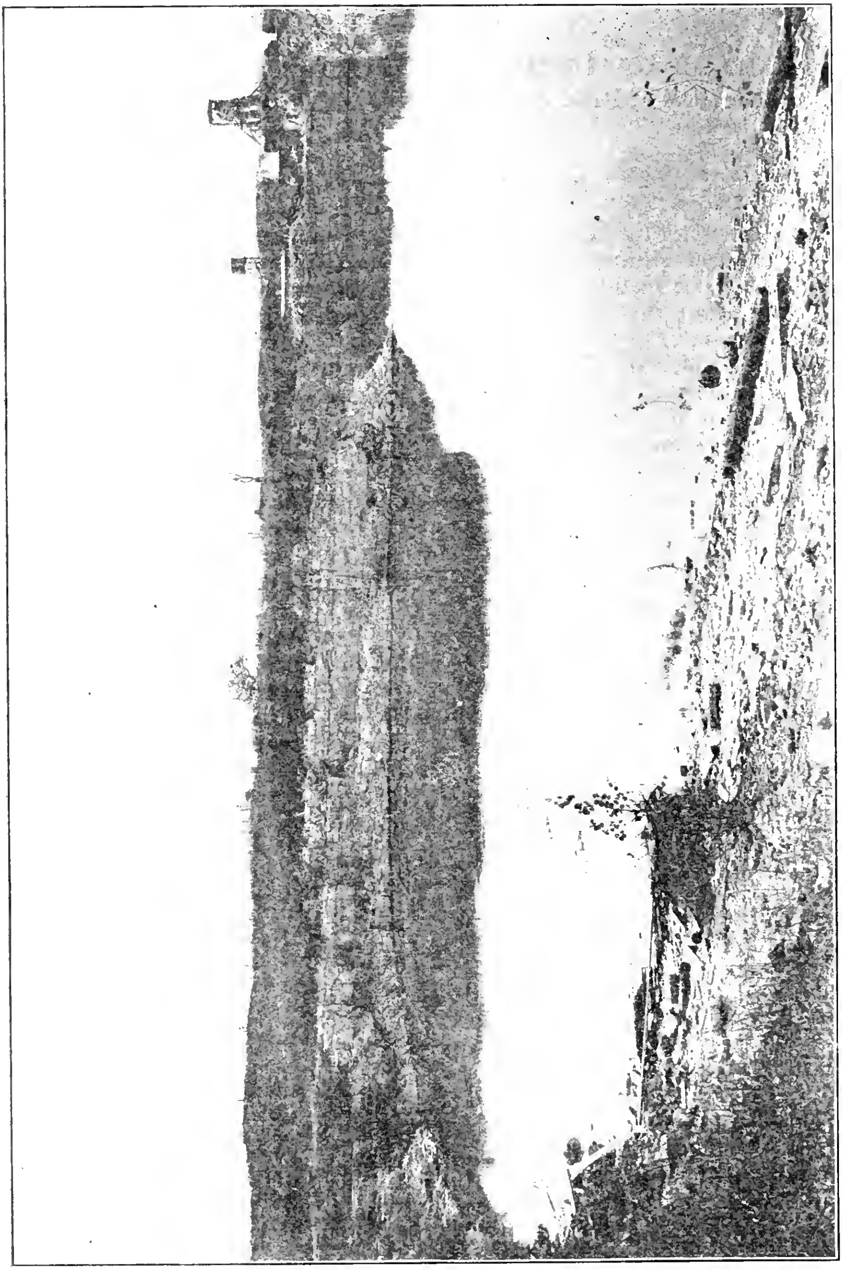
*The Dundee of Monroe county, as described by Professor Sherzer (Geological Report on Monroe County, Vol. VII, p. 1, Geological Survey of Michigan, 1900), is essentially a high grade limestone; whereas, in the Amherstburg quarries there are three several deposits, the lower averaging 97.5 Ca Co_3, the middle about 60.9, and the upper 80.+ (See Bureau of Mines, Ontario, 1904, Vol. II, "The Limestones of Ontario.)



High grade limestone quarry, at the Amherstburg Quarries, in spring-time, showing dip of strata. Essex County.

Were there sufficient exposure of the rock surface to facilitate observation, the dip of the overlying formation would doubtless be seen to circle round the anticlinal as this falls away eastward, until the north to northwesterly dip would be found again on the north side of the anticline, the same dip as on the opposite side of Detroit river.

Let it be noted that there *is* a Silurian surface extension immediately northward of the Amherstburg Quarries. The log of the Sucker Creek Oil and Gas Company's test well, lot 7, con. 6, in Anderdon Township (some six miles northeast from the point A[1] in the diagram), shows dolomite from the surface down, 350 feet of it over the Sylvania.

The Rock Surface of Essex County falls away eastward from an elevation of 609 feet at the quarries in Anderdon, to 533 feet at Essex town near the center of the county. There is a further fall to 476 feet at Comber, and to something less than this at the Kent county line. (This is a medial line, both territorially and with reference to surface drainage.) From the same starting point of 609 feet elevation, eastward through the southern part of the county, there is the same falling away, but less pronounced. At Marshfield, southeast from the highest point of rock elevation in the county, at the Amherstburg Quarries, and southwest from Essex town, the rock elevation is 521 feet. At Leamington, southeast of Essex town and south of Comber, it is 502 feet; and at the county line less than 500 feet. In the northern part of the county the elevation of the rock surface is 492 feet at Belle River; and there is evidence that it is lowest at the northeast corner of the county, at the mouth of the Thames river.

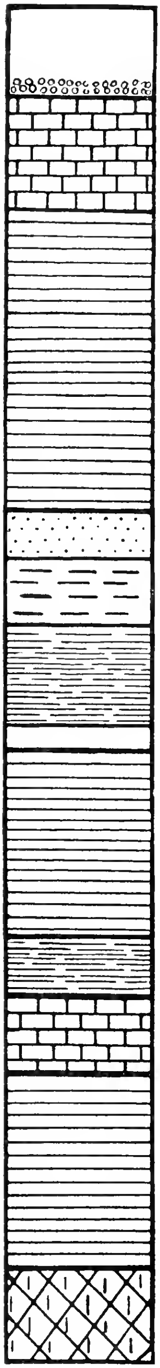
Were the analyses forthcoming they would, therefore, doubtless show, not only that the Corniferous extends into Essex county along the ascertained lines of outcrop in Monroe and Wayne counties, overlain northward by the Hamilton and Genesee, in order; but also that it circles round as above suggested to where it has the southward dip as exposed in the Amherstburg Quarries.

I make the statement on the authority of Mr. Eugene Coste, late mining engineer of the Geological Survey of Canada, who has done a great deal of exploring for gas and oil in both Essex and Kent counties, that "*the western limit of the black shale* is, roughly speaking, the Essex and Kent county line; and in places in Kent county these shales extend south as far as Lake Erie; although they are missing in Kent over a number of anticlinal folds." Thereby establishing two things: First, and incidentally, that the contour of the Antrim or Genesee shales, as figured in the 1903 report of the Michigan Geological Survey, errs by defect, as does also the outline mapped by the Dominion Government Survey, in showing the extent of these *shales; and second, (and more to the purpose of the argument in hand to establish the fact of a Silurian anticlinal in the western part of Essex county), that anticlinals have interfered to displace later deposits in this southwestern section of Ontario. A Silurian anticlinal is the solution of the problem offered. For that matter the Lime Kiln Crossing in the immediate neighborhood of the Amherstburg Quarries, in the Detroit River, known to sailormen as the danger spot of the lakes for deep draft boats, *is* part of a Silurian anticline.

* Well records show a varying depth of these shales at the North side of Kent County from Dresden to Bothwell, of 180 feet, 146 feet, 98 feet, 200 feet, and 77 feet.

SUCKER CREEK OIL AND GAS COMPANY'S TEST WELL, ANDERDON TOWNSHIP, ESSEX COUNTY, ONTARIO. ALT. 609 FT.

CHAS. W. MILLER, CONTRACTOR.—DRILLER'S LOG.



1-60 ft. Blue clay and gravel.

60-150. Gray limestone. Brisk effervescence. (At 72 ft. a strong flow of fresh sulphur water.)

150-410. *Brown* dolomites. Considerable effervescence at 400 ft.

410-440. Sylvania Sandstone.

440-500. Coarse-grained dolomite.

500-667. *Blue* dolomite.

667-683. Gypsum. No effervescence at 683.

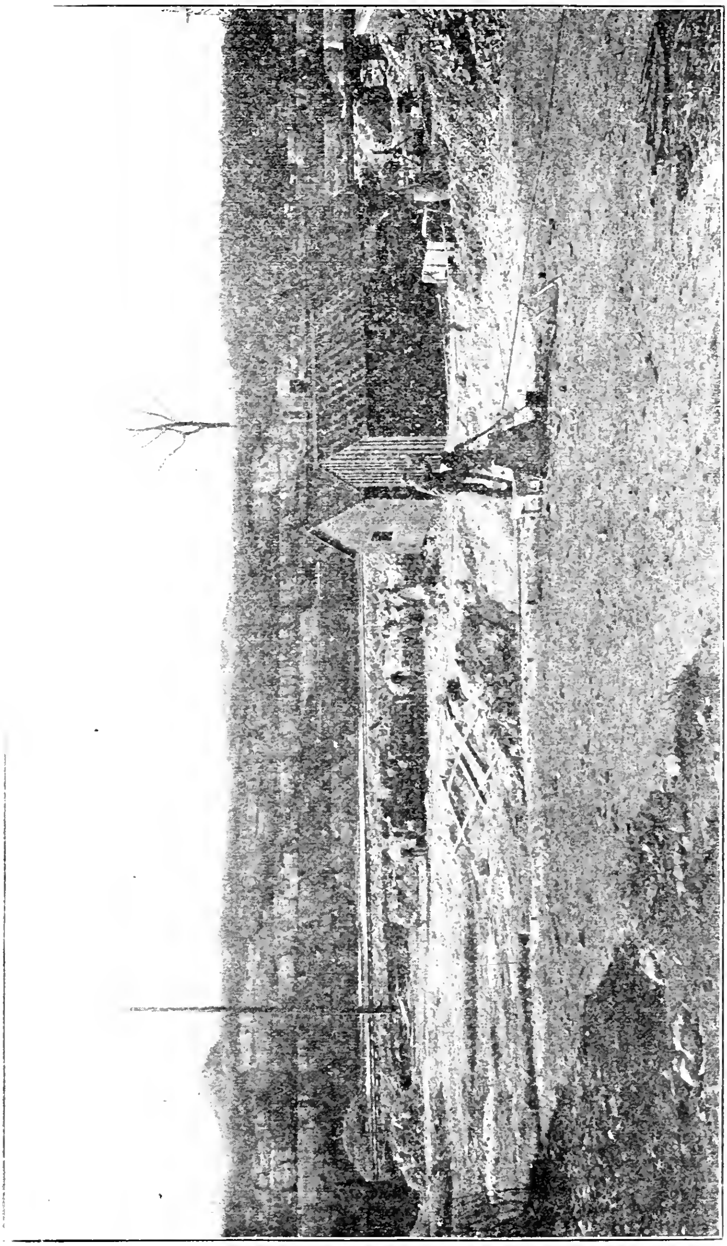
683-840. *Brown* dolomites. Remarkably soft to 720. ft. Very much harder to 760 ft., and darker to 840 ft. Considerable effervescence at 720 feet, and 840.

840-890. *Blue* dolomite. Effervescence from 890 feet down slow.

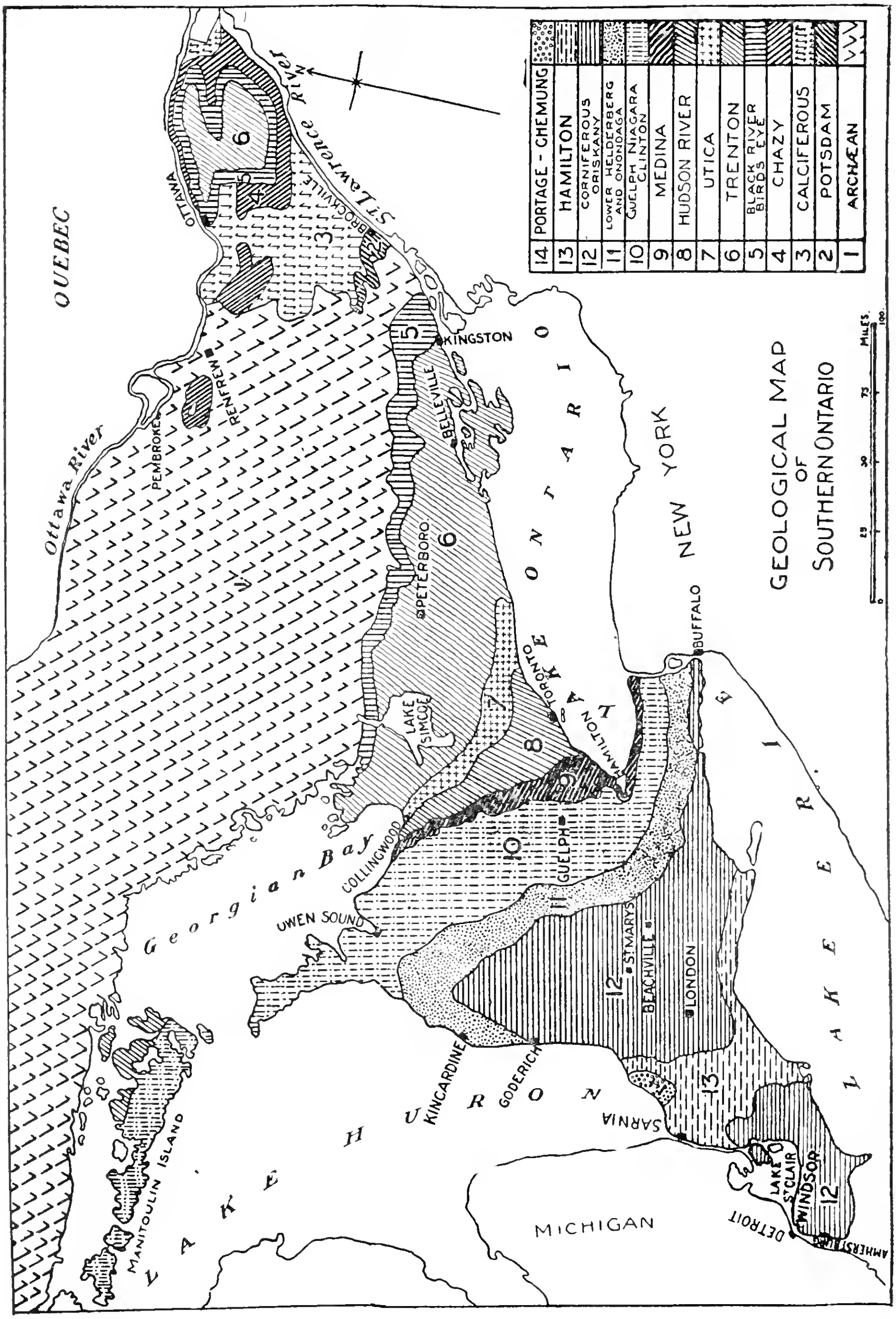
890-950. Light *gray* dolomite.

950-1125. Brown dolomite; fine; coarse; fine and harder. (A trace of salt sand together with a little salt water at 1075-1080.)

1125-1144. Salt sand and salt water, changing to a brown hard rock.

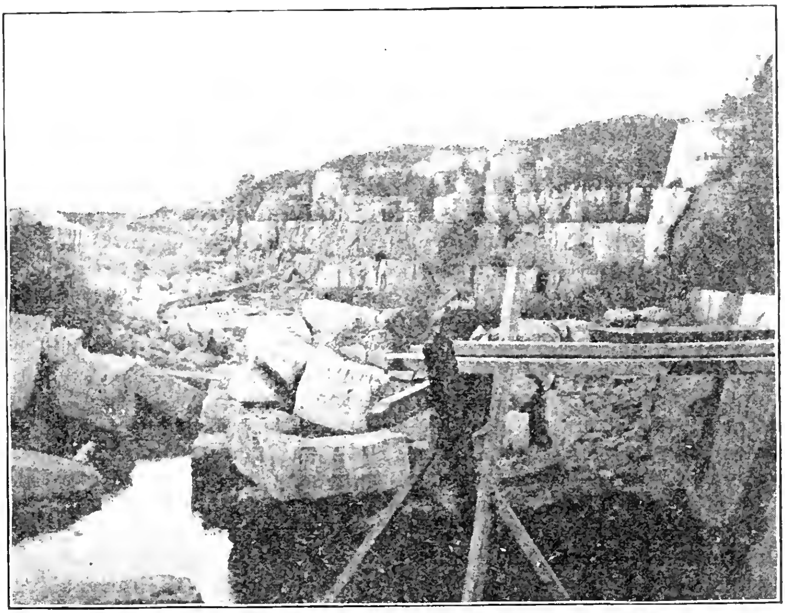


Quarry of gray dolomitic limestone, Anderdon, resting on high grade limestone floor; showing also (upper half of bluff), thin-bedded deposits. Essex County.


GEOLOGICAL MAP
OF
SOUTHERN ONTARIO
MILES
0 25 50 75 100
14 PORTAGE - CHEMUNG
13 HAMILTON
12 CORNIFEROUS ORISKANY
11 LOWER HELDERBERG AND ONONDAGA
10 GUELPH NIAGARA CLINTON
9 MEDINA
8 HUDSON RIVER
7 UTICA
6 TRENTON
5 BLACK RIVER BIRDS EYE
4 CHAZY
3 CALCIFEROUS
2 POTSDAM
1 ARCHÆAN
QUEBEC
Ottawa River
St. Lawrence River
OTTAWA
BROCKVILLE
PEMBROKE
RENFREW
KINGSTON
BELLEVILLE
PETERBORO
LAKE SIMCOE
TORONTO
HAMILTON
BUFFALO
LAKE ONTARIO
NEW YORK
Georgian Bay
COLLINGWOOD
OWEN SOUND
GUELPH
ST. MARYS
BEACHVILLE
LONDON
KINCARDINE
GODERICH
SARNIA
LAKE ERIE
LAKE HURON
MANITOULIN ISLAND
LAKE ST. CLAIR
WINDSOR
DETROIT
AMHERSTBURG
MICHIGAN

The Geology of the Western End of Lake Erie does not appear to have been very well worked out by either Michigan, Ohio, or Ontario. It is therefore with some diffidence that I advance an opinion. I am, however, convinced that those forces which gave rise to unconformity between the Silurian and the Devonian strata, caused an expansion of the Devonian sea southward and southeastward. In proof of this let it be stated that the rock outcropping on Pelee Island, and (as I am told) on Middle Island and Kelley's Island, in Lake Erie, is the same as that in the Amherstburg Quarries in Anderdon Township. The approximate limit of deposit of the Devonian westward corresponds, very probably, as nearly as may be, with the international boundary line until it passes North Bass Island, thence curving southward till it passes the west side of Kelley's Island. If this be (as I believe it to be), the delimitation of the Devonian in this direction, it follows that the Corniferous strata rest unconformably upon the earlier deposits of the upper Silurian at the west end of Lake Erie.

The surface extension over the entire upland of Pelee Island is the same thin-bedded limestone as lies over the heavy bedded stone in the Amherstburg Quarries. At the north end of the island the rock has faulted, leaving



Showing the heavy beds from which the block stone was quarried for the Canadian Sault canal locks, and for the old locks at the American Sault. The same quality of stone was taken from Pelee Island to build the locks at Port Colborne, on the Welland canal.

a bluff, with north exposure of the thin and heavy bedded lime. About the middle of the island on the west side, is another similar elevation of 598 feet to 608 feet, or thereabout, breaking off eastward at an angle with the north and south faces of the ridge. But at no place on the Island is there an exposure deep enough to show the high grade limestone that underlies the heavy beds.

The siliceous strata occurring in the Sibley quarry, near Trenton, Wayne

county, to which my attention was directed by Mr. K. J. Sundstrom, General Manager of the quarry, are of a later horizon than the thin-bedded strata in Anderdon and on Pelee Island. It would appear that the depositing of the same limestone beds has gone on for a long period in the Corniferous age, in Wayne county, after it had ceased in Essex county by reason of the elevation of the Devonian sea bottom. There is evidence of disturbing forces at work producing this uplift presented: (1) in the faulted and disturbed condition of the Lake Erie islands; (2) in the irregularly undulating surface of the Silurian rock in Detroit river bed and in Monroe county; and more particularly (3) in the fact of the absence of the later Corniferous beds on the Canadian side of the river which are present and exposed in the Sibley quarry.

It will not be without interest to note *the varying elevation of the Sylvania sandstone* which forms a very considerable surface extension in Monroe county. At Amherstburg, in the bed of the river, opposite the D., B. I. & W. Ferry Company's dock on Bois Blanc Island, it forms a surface extension over a very small area, at an elevation of 552.5 feet. At the Sucker Creek Gas and Oil Company's test well in Anderdon Township it occurs at the elevation of 199 feet. At the Salt Shaft below Detroit the elevation is 155 feet. At Belle River, about half way along the south side of Lake St. Clair, one record shows a sand rock at an elevation of 312 feet. Almost due south of this on Pelee Island, in Lake Erie, the elevation is, approximately, 300 feet to 325 feet.

In five wells put down by the Solvay Process Company, below Detroit, the *Sylvania Sandstone runs from 80 feet to 103 feet in thickness. Contrasted with this there is 84 feet of it in the †Parks Well in Malden Township, some two miles distant from the outcrop in the river bed between Bois Blanc Island and Amherstburg.† The Caldwell grove well a mile north from this shows 60 feet. In the ‡Anderdon well already referred to there is 30 feet. At Belle River, 25 feet. And‖ on Pelee Island, 40 feet.

The Depth of Till over the western half of Essex county varies from 60 feet to 110 feet. Mr. Coste, whose name was mentioned in connection with the Genesee shales, says: "The depth of the drift over the east half of Essex and the west half of Kent seems to vary from 90 to 200 feet, being mostly from 100 to 150. Its character varies a great deal but it most often consists of about 100 feet of boulder clay, and from 20 to 30 feet of sand or gravel under that." At Bothwell, at the northeast corner of Kent county, where the surface §elevation is 691 feet, there is a maximum depth of till, 255 feet.

The Point of Highest Elevation in Essex county is at Ruthven, on the old Talbot road, west of Leamington. Here there is a deposit of sand and gravel and boulders, of the Belmore Beach doubtless, with an elevation of 734 feet, the western limit of a ridge of the same material that extends parallel with Lake Erie almost its entire length, and which reaches a maximum elevation, for the two counties, of 736 feet near the southeast corner of Kent.

St. Andrew's Manse, Amherstburg, Ontario, March 8, 1907.

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* My Report on the Corniferous Exposure in Anderdon, Bureau of Mines, Ontario, 1902, page 123.

† Brummell's report on Natural Gas and Petroleum in Ontario, 1892, Geological Survey of Canada.

‡ Log of Sucker Creek Gas and Oil Company's well, Chas. W. Miller, drill contractor, 1905.

‖ Drillings examined by Dr. H. M. Ami, Ottawa, 1896.

§ Surface elevations quoted are as given in the Dictionary of Altitudes in Canada, by James White, F. R. G. S., Geographer to the Dominion Government Geological Survey. The rock elevations are from individual well records, except in the case of the Amherstburg Quarries and the Detroit River bed. These latter were ascertained by Mr. Charles Y. Dixon, of the U. S. War Department Office, Detroit.

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